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Electrical Engineering

June
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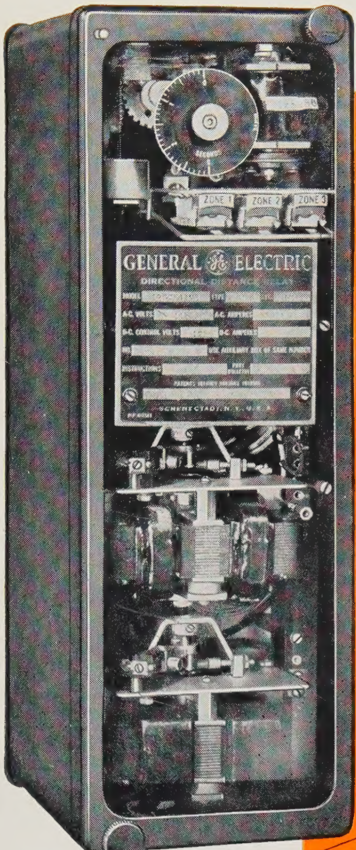

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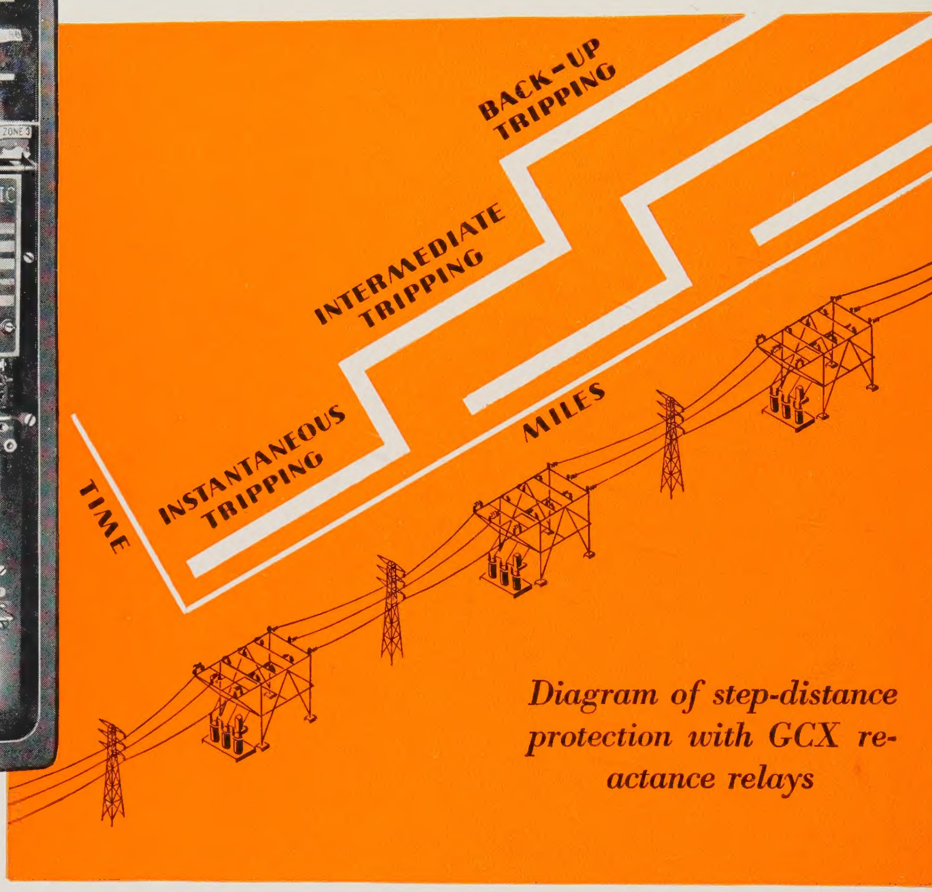

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Front Cover

The famous 200 inch astronomical mirror cast at the Corning Glass Works, last December, and now cooling. Production equipment for this mirror may be inspected during the Institute's forthcoming summer convention.

Photo by Ayres A. Stevens

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In This Issue—

PRINCIPAL engineering features of 3 large modern electric power generating stations are discussed in 3 papers appearing in this issue. In the first, the Boulder Dam hydroelectric plant now being constructed by the federal government on the Colorado River is described. This plant, half of which is in Arizona and half in Nevada, will have an ultimate capacity of 1,317,500 kva (*pages 583–94*). The second paper describes the Huntley station No. 2, largest 60-cycle steam-electric generating station of the Niagara-Hudson system and a thoroughly modern plant (*pages 632–45*). In the third paper, the rehabilitation program for the Connors Creek plant in Detroit, Mich., is outlined. This paper should be of particular interest to engineers of power companies still operating obsolete or obsolescent equipment (*pages 610–17*).

MANY processes in modern steel mills depend upon drive characteristics that can be obtained only with electric motor. The special requirements of the steel mill, however, demand specially designed equipment for these electric drives; some of this equipment is described in 2 papers in this issue. One paper describes circuit breakers for use in d-c steel mill circuits in which currents are extremely high and have a high rate of rise (*pages 594–8*); the other describes automatic and semiautomatic screw-down equipment for 3-high roughing mills (*pages 651–5*).

READING lists for junior engineers have been appearing month by month in ELECTRICAL ENGINEERING since December 1934. The concluding section of this list, prepared by the committee on professional training of the Engineers' Council for Professional Development, appears in the present issue (*page 681*). This reading list, together with a method of self-appraisal and critical analysis to assist the junior engineer in improving himself, have been combined in a pamphlet made available by the E.C.P.D. (*pages 676–7*).

KNOWLEDGE of the purposes, accomplishments, and future plans of the 4 national engineering societies known as the "founder societies," and of their several jointly sponsored functional organizations, was made available at a meeting held recently in the Engineers' Club, New York City. That members may be informed of these activities, detailed reports of the information presented at the meeting are being published in this and future issues (*page 677*).

NATIONAL Institute prizes have been announced for all classes of papers presented during 1934, and district prizes have been announced by 3 of the Institute's districts. The high caliber of papers submitted made selection difficult in several cases. Authors presenting papers before the Institute during 1935 should bear in mind that to be considered for prizes, the papers must be submitted specifically for that purpose, to the proper committee (*page 677*).

AUTOMATIC resistance-type metal heaters for heating metal bars, rods, rivets, and similar parts to a heat treating or forging temperature by passing electric current through them, have been made practical by the development of photoelectric temperature control. Increased production and better temperature regulation than can be obtained with manually controlled heaters are 2 of the principal advantages of the automatic control (*pages 645–50*).

HAZARDS resulting from the complexity of modern living and the ingenious audacity of the modern crook contribute greatly to the interest and possibilities in the field of protective signaling as well as to the difficulty of providing adequate protection. Modern electrical signaling systems for protecting property and life against fire, burglary, robbery, and related risks, are described in this issue (*pages 617–23*).

BREAKDOWN strength and dielectric loss of mica tape insulation have been improved materially by the development of an improved bonding compound, by exercising more effective control over the quality of component materials, and by improved methods of manufacture and application. Present mica tape insulation is said to be adequate for stator windings of 33,000 volt generators (*pages 624–31*).

CORNELL University, Ithaca, N. Y., will be the scene of the Institute's 51st annual summer convention, June 24–28, 1935. The technical program, discussion conferences, inspection trips, and entertainment features were outlined in the May issue of ELECTRICAL ENGINEERING (*pages 560–4*). The final announcement, together with the subjects of additional conferences, are given in the present issue (*pages 668–9*).

FULL-VOLTAGE starting of a-c motors causes high transient voltages across some of the turns of the machine windings. Capacitors connected between each phase of the winding and ground near the machine terminals have been found to provide effective protection against these transients *pages 599–603*).

SPARKLESS sphere gap method of measuring very high voltages, in which the spheres are held at a distance greater than the spark-over distance and the voltage is determined from the mechanical force between the spheres, has several advantages over the conventional spark-over method (*pages 655–60*).

INSTITUTE Section and Branch activities for the year 1934–35 have been summarized in the annual report. Data on the number of meetings held and the attendance for each Section and each Branch, together with data on Student conferences and conventions, and joint Section and Branch meetings are included (*pages 674–5*).

OKLAHOMA City was host to the Institute's South West District at the meeting held there April 24–26, 1935. Records were set in attendance and in the interest of those attending. A symposium on engineering education and the Student sessions played a prominent part in the meeting (*pages 670–2*).

A STUDENT conference of all the Institute's branches in the Southern District (number 4) was held at Virginia Polytechnic Institute, Blacksburg, April 11–13, 1935. One hundred and sixty-two were registered at this interesting meeting, at which several outstanding student papers were presented (*page 676*).

RESEARCH on insulating liquids shows that the conductivity-time relations, the reduction of conductivity and dielectric loss by the continuous application of continuous potential, and the occurrence of space charges at the electrodes are intimately related phenomena (*pages 603–9*).

PROGRESS of the Federal work-relief bill, the survey of the engineering profession being made by the U.S. Bureau of Labor Statistics, and other items of interest to engineers are contained in the current news letter of American Engineering Council (*pages 682–3*).

IMPROVEMENTS in electronic tubes have provided the basis for development of many controlling and regulating devices; one such device for automatically regulating the voltage of an alternator is described in this issue (*pages 663–7.*)

DISCUSSIONS of A.I.E.E. papers have been omitted from this issue in order that more space might be devoted to the publication of summer convention papers.

Engineering Features of Boulder Dam and Power Plant

By
L. N. McCLELLAN
MEMBER A.I.E.E.
U.S. Bureau of Reclamation, Denver, Colo.

The combination flood control, water conservation, and power development now being constructed on the Colorado River by the federal government represents one of the outstanding engineering achievements of recent years. The dam, which is 726 feet high and 1,180 feet long at the crest, and which contains 3,250,000 cubic yards of concrete, will create a reservoir having a capacity of 30,500,000 acre-feet, a length of 115 miles, and a maximum width of about 8 miles. The power plant is designed for an ultimate installation of 15 82,500 kva units and 2 40,000 kva units, making a total ultimate capacity of 1,317,500 kva; 4,330,000,000 kilowatt-hours of firm energy and an average of 1,500,000,000 kilowatt-hours of secondary energy per year will be made available. The principal engineering features of the dam and power plant and appurtenant structures and equipment are described in this paper.

THE Boulder Canyon Project which now is being constructed by the federal government under the provisions of the Boulder Canyon Project Act is located on the Colorado River where it forms the boundary between the states of Arizona and Nevada, about 25 miles southeast of Las Vegas, Nev. The project is a combination flood control, water conservation, and hydroelectric power development. The need for flood control is very urgent as the danger of loss of life and property from floods in the lower valleys is increasing constantly as the bed of the river is built up by the deposition of silt in the delta region. There is also a very definite need for conservation of the waters of the Colorado River for both irrigation and domestic purposes. The cities of southern California now are looking to the Colorado River for their future water supply, and the natural flow of the river is inadequate for present irrigation requirements.

Electric power that will be made available by Boulder dam will be used for commercial and industrial purposes in southern California, Arizona, and Nevada, and for pumping water through the aqueduct of the Metropolitan Water District of Southern California. Contracts have been entered into with the Metropolitan Water district of Southern California, the cities of Los Angeles, Burbank, Glendale, and Pasadena, The Southern California Edison Company, Ltd., The Southern Sierras Power Company, and The Los Angeles Gas and Electric Corporation. These contracts provide for the disposition of all electric energy that will be available and insure sufficient revenue to repay the entire cost of the project, including interest charges at the rate of 4 per cent per annum, within 50 years; in addition they provide for annual payments to each of the states of Arizona and Nevada of approximately $625,000 in lieu of taxes.

Dam and Reservoir

The dam is a concrete structure of the arch-gravity type, 726 feet high from lowest point of foundation to roadway, 1,180 feet long at the crest, 660 feet thick at the base, and 45 feet thick at the top. The dam will raise the water surface 584 feet above normal low water in the river and will contain 3,250,000 cubic yards of concrete.

The reservoir created by the dam will have an area of 227 square miles, a capacity of 30,500,000 acre-feet, a length of 115 miles, and a width at the widest point of 8 miles. The lake thus created will be the largest artificial lake in the world. The top 9,500,000 acre-feet of storage capacity is allocated to flood control; the bottom 5,000,000 acre-feet is reserved for storage of silt which will accumulate in the reservoir at the rate of 137,000 acre-feet per year; and the middle 16,000,000 acre-feet will be active storage to regulate the stream to suit the needs of irrigation and power.

Power Output and Plant

The annual runoff of the Colorado River at Boulder dam varies from a minimum of 4,300,000 acre-feet to a maximum of about 25,200,000 acre-feet with an average of 15,000,000 acre-feet. The Boulder dam will make available a firm continuous

A paper recommended for publication by the A.I.E.E. committee on power generation, and scheduled for discussion at the A.I.E.E. summer convention, Ithaca, N. Y., Jun. 24–28, 1935. Manuscript submitted Mar. 15, 1935; released for publication April 1, 1935.

The author acknowledges the co-operation in working out plans for the power plant of the following: E. F. Scattergood, Bureau of Power and Light of the City of Los Angeles, and staff; F. E. Weymouth, and J. M. Gaylor, Metropolitan Water District of Southern California; H. A. Barre (deceased) and N. B. Hinson, Southern Calif. Edison Co., and staff; R. H. Halpenny, Southern Sierras Power Co. The author also acknowledges the assistance of engineers of the General Electric Company and Westinghouse Electric and Manufacturing Company in preparing designs and specifications for the electrical equipment installed in the plant. The design of the Boulder power plant was prepared under the direction of the author. All designs prepared by the Bureau of Reclamation are under the general direction of J. L. Savage, chief designing engineer; all engineering and construction work is under the direction of R. F. Walter, chief engineer with headquarters at Denver, Colo.; and all activities of the bureau are under the general charge of Dr. Elwood Mead, commissioner of reclamation, with headquarters at Washington, D. C.

output of 663,000 horsepower or 4,330,000,000 kilowatt-hours of firm energy per year. The amount of firm energy will be reduced gradually by future upstream developments, and it is estimated that the reduction in firm energy from this cause will be at the rate of 876,000 kilowatt-hours per annum. In addition to the firm energy, large amounts of secondary energy will be available during periods when the runoff of the river is above average. It is estimated that an average of 1,500,000,000 kilowatt-hours of secondary energy will be available per year.

The Boulder power plant is designed for an ultimate installation of 15 main generating units of 82,500 kva capacity each and 2 main generating units of 40,000 kva capacity each, making a total generating capacity of 1,317,500 kva. The initial power installation comprises 4 82,500 kva units and one 40,000 kva unit. The initial installation will be ready for operation about March 1, 1936. Two additional 82,500 kva units will be ready for operation about January 1, 1938, and subsequent units will be added as needed.

Figure 2 shows the general plan of the dam, power plant, and related features and figure 3 is a typical cross section through a main generating unit.

Spillways

Two spillways are provided, one on each side of the river. Each spillway consists of a concrete lined open channel about 650 feet long, 150 feet wide, and 120 feet deep with the side next to the river formed into an ogee-shaped crest. On top of the crest are mounted 4 steel drum gates, each 100 feet long and 16 feet high, which may be controlled either automatically or manually. Each spillway has a maximum discharge capacity of 200,000 cubic feet per second. The flow over each spillway when discharging full capacity would be about the same as the flow over Niagara Falls, and the total drop would be more than 3 times as great. The spillways discharge through inclined shafts 50 feet in diameter and 600 feet long into the outer 50 foot diversion tunnels which return the water to the river below the dam.

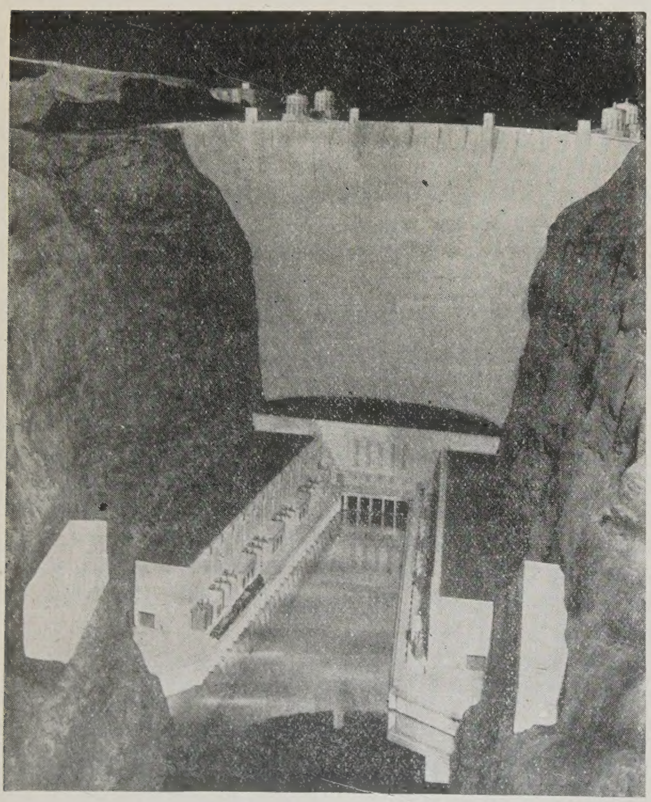

Fig. 1. A model of Boulder dam and power plant showing general arrangement of structures

Intake Towers

Four intake towers, 2 on each side of the river a short distance upstream from the dam, control the upper ends of the 4 30 foot outlet pipes through which water is conducted to the turbines in the power plant and to the discharge valves. The intake towers are reinforced concrete structures 403 feet high from base to top of dome. Each tower consists of an inner cylinder with an inside diameter of 29 feet 8 inches and with 12 radial buttresses which support the trash racks and emergency bulkhead gates. The towers are 82 feet in diameter at the base and 64 feet at the top.

Each intake tower is provided with 2 steel cylinder gates, one at the base of the tower at elevation 895 feet and the other about half way up the tower at elevation 1,045 feet. These gates have an outside diameter of 32 feet and a vertical travel of 9 feet. In normal operation both upper and lower gates will be fully open. When the water is to be shut off from any one of the outlet pipes the lower gate will be closed first under balanced pressure, and then the upper gate will be closed. Under this procedure the cylinder gates never will have to be operated under an unbalanced head greater than 170 feet. Normally these gates will be opened and closed with the pressures on the inside and outside of the gates equalized.

In order to make it possible to inspect and repair the cylinder gates provision is made for placing cast steel bulkhead gates over the 12 entrances to each cylinder gate. Grooves in the radial buttresses are provided for lowering the bulkhead gates into position, and each intake tower is provided with a special revolving electric crane for raising and lowering these gates.

Spaces between the radial buttresses of the intake towers from elevation 894 feet to elevation 1,200 feet are provided with steel trash racks to prevent trash from entering the towers.

Outlet Pipes and Penstocks

There are 4 independent penstocks each consisting of a main penstock 30 feet in diameter with 4 branch penstocks each 13 feet in diameter leading to the turbines and a pipe 25 feet in diameter extending from the main penstock to a group of 6 needle valves on the downstream end. The penstocks are made of plate steel varying in thickness from $2^3/_4$ inches to $^5/_8$ inch. All shop joints are electrically welded and stress-relieved, and each weld is inspected by means

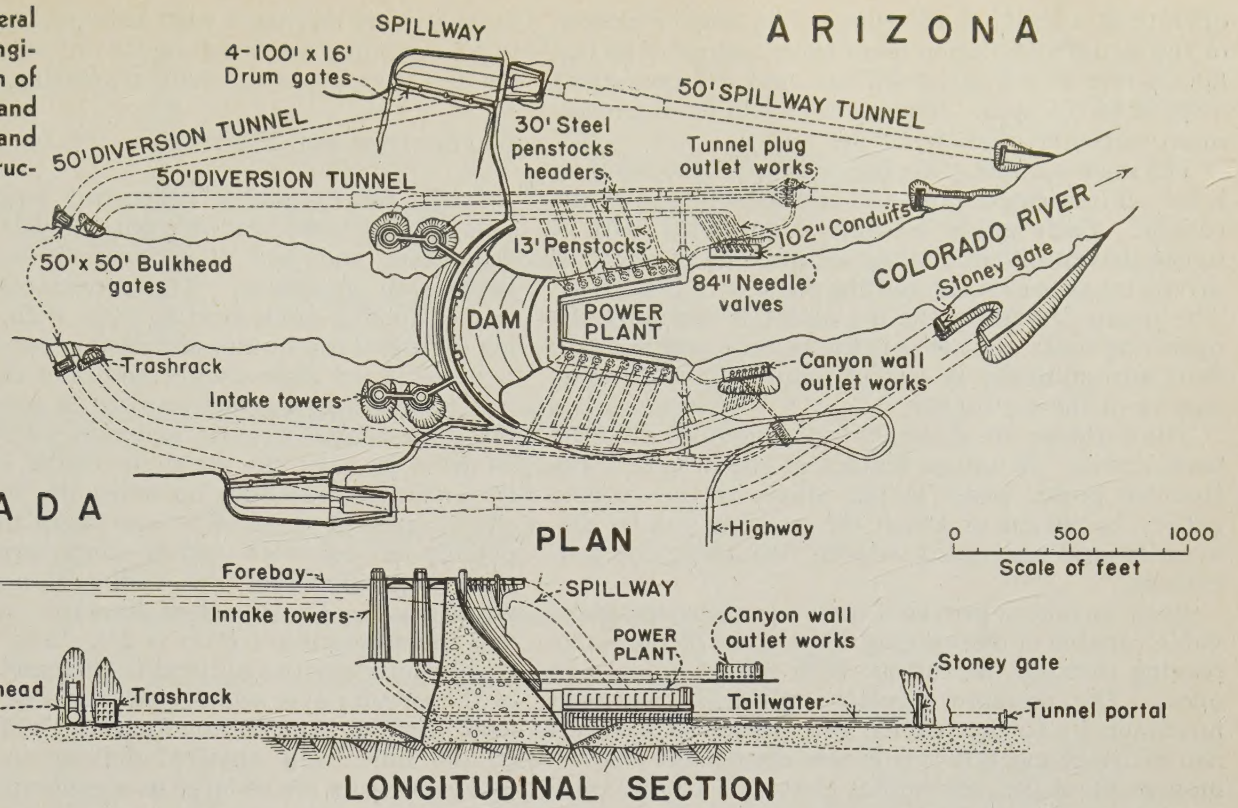

Fig. 2. General plan and longitudinal section of Boulder dam and power plant and appurtenant structures

of X ray photographs. Erection joints between sections of pipe consist of a special type of welded and riveted girth joint. The girth joint consists of a butt strap of the same thickness as the pipe shell electrically welded to one end of each section of pipe in the shop. This butt strap has a shrink fit over the end of the adjoining pipe section; after being shrunk on, it is attached to the adjoining pipe section by means of a double row of steel pins pressed into place and locked by trepanning the plate around the pin and then peening the plate under the head of the pin. The pins vary in diameter from $1^1/_2$ to $3^1/_{16}$ inches. The penstocks comprise 4,700 feet of 30 foot main headers, 1,900 feet of 25 foot pipes, 5,800 feet of 13 foot penstocks leading to the turbines in the power plant, and 2,000 feet of $8^1/_2$ foot pipes leading to the needle valves. A total of 44,000 tons of steel plate is required for the fabrication of the steel outlet pipes and penstocks.

Butterfly Valves

Each main turbine has a butterfly-type hydraulic-rotor-operated shutoff valve at the inlet to the turbine casing. Valves for the 115,000 horsepower turbines are 14 feet in diameter and those for the 55,000 horsepower turbines are 10 feet in diameter. The valves are designed for closure under a pressure of 300 pounds per square inch and with a flow of 8,000 cubic feet per second through the larger valves and a corresponding flow through the smaller valves. Each 14 foot valve has 2 by-passes each 12 inches in diameter, and each 10 foot valve has 2 by-passes each 8 inches in diameter. Each by-pass is provided with one motor-operated needle-type service valve and one hand-operated gate valve for emergency closure.

The hydraulic rotor is enclosed in a fixed vertical cylinder and is connected directly to the upper end of the stem of the butterfly valve. Oil under pressure may be applied to either side of the 2 vanes of the rotor causing the valve either to open or to close. A brake or locking device is incorporated in the rotor for automatically locking the valve in any position; this brake is released automatically by oil pressure when the valve is being operated. Each butterfly valve has an individual motor-operated high-pressure oil pump which supplies oil under a maximum pressure of 1,800 pounds per square inch for operating the hydraulic rotor.

Normally, the butterfly valves will be operated under balanced pressure. They will not be closed until after the turbine wicket gates are closed; and they will not be opened until after the by-passes have been opened, the turbine casing filled, and the pressure therein is equal to the pressure in the penstock. The butterfly valves are arranged for remote control from the switchboard and the operation is entirely automatic.

Turbines

Turbines are of the vertical-shaft single-runner Francis type with cast steel spiral casings and single-piece cast-steel runners. They are designed to operate under a net effective head varying from a minimum of 360 feet to a maximum of 590 feet. These extreme head conditions will prevail only at infrequent intervals of short duration. For 90 per cent of the time the net effective head will be between 450 and 560 feet and the average net effective head will be 530 feet. The 4 large turbines of the initial installation have a rated output of 115,000 horsepower each at a head of 492.5 feet and will

operate at a speed of 180 rpm. The smaller turbine of the initial installation has a rated output of 55,000 horsepower at a head of 467 feet and will operate at a speed of 257 rpm. The turbines will have a maximum efficiency of about 92 per cent.

The main turbine guide bearings are of the babbitt-lined oil-lubricated type and are located above the runner. Each guide bearing is provided with 2 motor-driven oil-circulating pumps, one of which is driven by an a-c motor and the other by a d-c motor. The pump driven by the a-c motor is normally the operating unit; the other is the reserve unit and will start automatically in case of failure of the oil pressure or of the a-c supply.

The turbines are designed for removal of all parts from above. A unique feature of the design of the Boulder power plant is the crane in the turbine gallery by means of which the turbines can be dismantled and assembled without disturbing the generators.

Each turbine is provided with a pressure regulator valve capable of discharging 80 per cent of the water passing through the turbine with wicket gates wide open. The pressure regulator valve is connected mechanically to the turbine gate operating mechanism with a connection of sufficient strength to prevent movement of the servomotor pistons if the pressure regulator valve sticks or fails to open. Each pressure regulator valve discharges into a cast steel energy absorber where the energy of the jet will be dissipated largely as heat.

Governors

Governors are of the oil-pressure relay-valve actuator type with speed responsive element, driven by an a-c motor which receives its power supply from a small permanent magnet type a-c generator direct connected to the shaft of the main generating unit. The speed responsive elements are sensitive to speed changes of 1/100 of one per cent. The governor equipment is designed for an oil pressure of 300 pounds per square inch, although it is probable that somewhat lower pressure actually will be used.

Governor oil systems are arranged so that the servomotors of 2 turbines and 2 actuators are served by one twin pumping unit consisting of 2 motor-driven gear-type oil pumps. The oil piping between pumps, pressure tanks, actuators, servomotors and sump tanks is arranged so that any part of the oil system can be taken out of service for maintenance or repairs without interfering with the operation of the main generating units. The oil pumps are controlled automatically, and either pumping unit may be used for normal operation with the other serving as a reserve. The second pumping unit is arranged to start automatically if either the oil pressure or oil level in the pressure tanks falls below a predetermined amount.

The actuators, oil pumping units, pressure tanks, and sump tanks are located in the governor gallery where the operation of all hydraulic equipment is centralized at the same elevation as the main turbine floor, which results in the minimum amount of oil piping between the actuators and servomotors. The actuators are equipped with automatic speed matching devices and are designed for full automatic starting and stopping of the main generating units.

Generators and Exciters

Initial installation of generating equipment consists of 4 82,500-kva 180-rpm 60-cycle 16,500-volt generators and one 40,000-kva 257-rpm 60-cycle 13,800-volt generator. The generators are of the conventional 2-guide-bearing type with thrust bearing on top of the frame, and each generator has a direct connected main exciter and pilot exciter.

The 82,500 kva generators are in several respects the largest hydroelectric generators built thus far. In order to meet the requirements of long distance transmission they have an unusually large flywheel effect (moment of inertia)—equivalent to 110,000,000 pounds at one foot radius—approximately twice what a generator of this rating of normal design would have. The transient reactance is 21 per cent and the short-circuit ratio is 2.4. The special electrical characteristics all tend to increase the stability of the circuits over which power will be transmitted from Boulder Dam to Los Angeles, Calif., a distance of 266 miles. In physical dimensions the 82,500 kva generators are as large as a generator of 125,000 kva capacity of normal design. They are 40 feet in diameter and 32 feet high above the base, and each generator weighs approximately 2,000,000 pounds. The rotor weighs approximately 1,100,000 pounds.

The 40,000 kva generator has a flywheel effect of 10,000,000 pounds at one foot radius, a transient reactance of 26 per cent, and a short circuit ratio of 1.6. This machine is 32 feet in diameter and 19 feet high above the base, and weighs 720,000 pounds. The rotating parts weigh 340,000 pounds.

Generator shafts are made of forged heat-treated carbon steel with coupling flanges forged integrally with the shaft. Shafts of the 82,500 kva generators are 38 inches in diameter and weigh approximately 100,000 pounds. The shaft of the 40,000 kva generator is 25 inches in diameter and weighs about 35,000 pounds. Each shaft has an inspection hole approximately 6 inches in diameter bored axially throughout its length for inspecting the metal in the interior.

The generators are provided with air operated brakes having sufficient capacity to bring the rotating parts to a stop from half speed within $7^1/_2$ minutes. The brakes are designed to be used as hydraulic jacks for raising the rotating parts off the thrust bearing, and a portable motor operated high pressure oil pumping unit is provided for operating the jacks.

Each generator is provided with a thrust bearing located on top of the machine and supported by the upper bearing bracket which carries the weight of the rotating parts of the generator and turbine. The Allis-Chalmers and Westinghouse generators have Kingsbury type thrust bearings, and the General Electric generators have spring type thrust bearings.

Each generator has an enclosed ventilating system with surface coolers through which cold water is circulated for removing the heat from the circulating

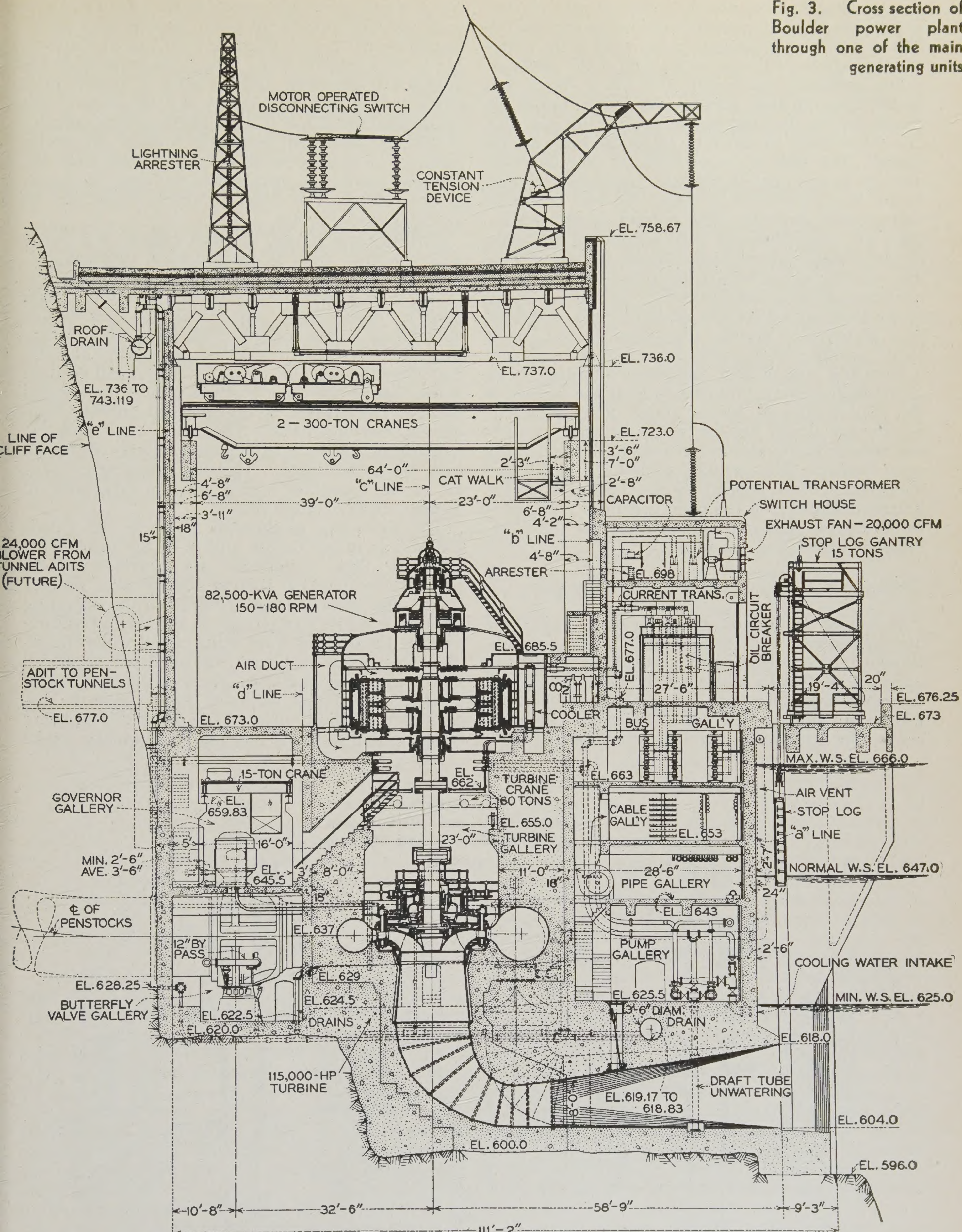

Fig. 3. Cross section of Boulder power plant through one of the main generating units

air. Each generator also is equipped with carbon-dioxide-gas fire-extinguishing equipment arranged to fill the generator housing automatically if the differential relays operate because of a fault in the windings.

For excitation, each generator has a direct-connected 250-volt main exciter mounted on top of the thrust bearing housing and a direct-connected 250-volt pilot exciter mounted on top of the main exciter frame. The leads of the main exciter are connected directly to the field of the main generator without circuit breaker or field rheostat. Control of exciter voltage and generator field current is effected entirely by controlling the field current of the main exciter which is accomplished by an automatic voltage regulator of the high-speed bridge type with non-continuously vibrating contacts. The voltage regulators are designed to respond to changes in voltage in a period of 3 cycles. The voltage of the pilot exciter is adjusted manually by a field rheostat, and a vibrating type of field contactor controlled by an overvoltage relay is provided to limit the voltage of the pilot exciter at speeds above normal. A 200 ampere air circuit breaker with discharge contacts and resistor is provided in the leads to the field of the main exciter. This breaker normally is closed and opens only when tripped by the operation of the differential relays on the main generator. Figure 4 shows cross sections of the General Electric and Westinghouse 82,500 kva generators.

Generator Voltage Oil Circuit Breakers

Generator voltage oil circuit breakers are of the metal-enclosed triple-pole single-throw non-oil-throwing indoor type with vertical lift; they are operated electrically and are fully automatic. All current carrying parts are enclosed in metal housings which provide complete phase isolation. Breakers connecting the 82,500 kva generators and the 165,000 kva banks of transformers to the bus have a current carrying capacity of 4,000 amperes and are insulated for 23 kv; they have an interrupting capacity of 2,500,000 kva. The breaker between the 40,000 kva generator and its bank of transformers has a current carrying capacity of 2,000 amperes and is insulated for 15 kv; it has an interrupting capacity of 500,000 kva. All generator voltage oil circuit breakers have an over-all operating time, from the time the trip coil is energized to the time the circuit is interrupted, of 8 cycles (60 cycle basis) and an arcing time of 2 cycles.

Briefly, these circuit breakers consist of 2 parts: a fixed portion with heavy structural steel supporting structure, fixed disconnecting contacts, and the raising and lowering mechanism; and a movable portion consisting of the circuit breaker proper with movable disconnecting contacts. Four large threaded screws with traveling nuts serve to raise and lower the movable portion. The raised position is the normal operating position, and in the lowered position the breaker is disconnected entirely from current carrying parts. The raising and lowering mechanism is motor operated and remotely controlled from the switchboard. The disconnecting contacts are of the laminated spring pressure type with all contact surfaces silver plated.

The operating mechanism of these oil circuit breakers is motor driven and is of the mechanical trip free type. Interlocks are provided which: prevent the movable portion (the breaker proper) from being lowered from or raised to the operating position when its contacts are in the closed position; prevent the breaker from being closed while the removable portion is being removed from or placed in the operating position; prevent the removal of breaker tanks except when the breaker is in the disconnected position; prevent the breaker from being raised to the operating position if the breaker tanks

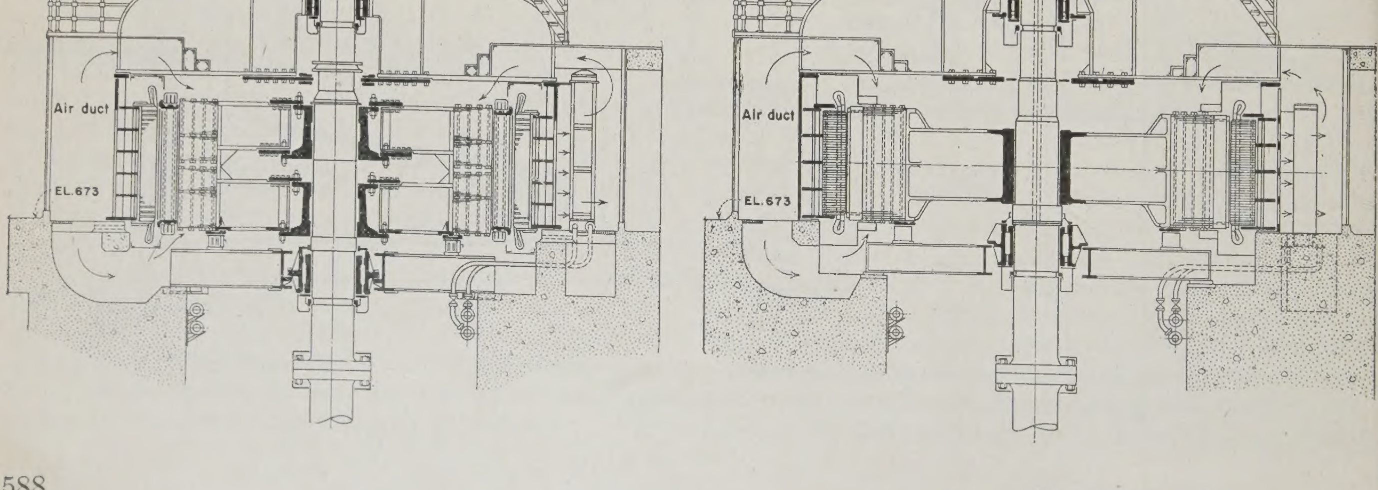

Fig. 4. Cross sections of General Electric (left) and Westinghouse (right) 82,500-kva 150–180-rpm generators

are not in place; prevent the doors affording access to the interior of the housing from being opened if the breaker is in the closed position; and prevent the breaker from being closed, except in the test position, if the doors to the housing are open. Figure 5 is a one line diagram of the principal electrical equipment showing the high and low voltage switching scheme.

23-Kv Connections and Bus Structure

Connections between generators and transformers and the generator transfer bus are all of the air-insulated metal-enclosed type. The conductors consist of 2 6 inch copper channels, with the flanges toward each other forming a hollow square section with a small ventilating space between the edges of the flanges. Each channel has a cross-sectional area of 2.92 square inches. The channels are clamped rigidly at 18 inch intervals by specially designed spacer clamps. Expansion joints consisting of several thin copper sheets are provided at frequent intervals to allow for expansion of the bus sections. Contact surfaces of all splices, expansion joints, and connections are silver plated in order to reduce contact resistance and minimize local heating.

Bus bars are supported on single piece porcelain insulators with nonferrous caps and pins. Bus supports are spaced 6 feet apart, and they have a strength in cantilever of 60,000 inch-pounds, a rated dry flashover voltage of 85 kv, a rated wet flashover voltage of 40 kv, and a leakage distance of 13.5 inches. The bus housing and the barriers between phases are made of hard rolled copper $^1/_8$ inch thick. Copper was selected for the bus enclosure after tests showed the desirability of a low resistance material in order to reduce the eddy current losses. Removable panels are provided in the housing at each bus support to facilitate inspection and cleaning of the insulators. The bus structure provides complete phase isolation.

The 23 kv bus structure is located in a gallery along the river side of each wing of the power plant and across the central section immediately below the transformer deck. Artificial cooling is provided for the bus gallery to remove the heat produced by the electrical losses in the bus and housing.

Power Transformers

The initial installation of power transformers consists of: 7 single-phase oil-insulated water-cooled units each rated 55,000 kva, 16,320 volts delta to 287,500 volts wye, 60 cycles; and 4 single-phase oil-insulated forced-oil-cooled units each rated 13,333 kva, 13,600–16,320 volts delta to 138,000 volts wye, 60 cycles. The transformers are of the inert gas filled outdoor type with shielded windings. The high voltage bushings are of the oil filled type and are provided with capacitance taps and accessories for supplying 115 volts for voltage indication and relay operation.

The transformers are placed on a platform along the river side of the wings of the power plant and over the draft tubes of the turbines. Fire walls separate the transformers, and fire protection is provided by means of a water curtain over the top and front of each transformer bay.

The 55,000 kva transformers will be shipped from the factory with core and coils completely assembled in a special tank car. The transformer cases will be shipped in 2 sections which will be welded together electrically at destination.

High Voltage Switching Equipment

High voltage switching stations are located on the Nevada side of the river a short distance back from the canyon rim. The initial installation of high voltage switching equipment comprises 4 287.5 kv oil circuit breakers on the 2 transmission circuits that the Bureau of Power and Light of the City of Los Angeles is building from Boulder Dam to Los Angeles. These oil circuit breakers are of the dead-tank high-speed type designed to operate in less than 3 cycles (60 cycle basis). They have an interrupting capacity of 2,500,000 kva and have 6 breaks per pole, each break being equipped with a deionizing grid arc extinguishing device.

Each oil circuit breaker is provided with motor-operated vertical-break disconnecting switches on each side. The disconnecting switches have 3 pillar type insulator supports per pole, one of which rotates to operate the blade and the other 2 fixed. The 2 disconnecting switches for one oil circuit breaker are arranged to operate from a single control, and interlocks are provided to prevent the disconnecting switches from being opened or closed except when the oil circuit breaker is open. Oil circuit breakers, disconnecting switches, and grounding switches are operated by remote control from the main switchboard in the control room of the power plant, and they may be operated also from local push button control stations at the switching station.

The high voltage switching station is provided with oil storage, handling, and treating facilities for treating the oil in the circuit breakers. Four oil storage tanks of 7,500 gallons each are installed in the basement of the control house. Two of these tanks will be kept full of clean oil; the others will be kept empty, ready to receive dirty oil from the circuit breakers. A portable oil purifying outfit consisting of a centrifuge and filter press capable of treating 1,200 gallons per hour is provided at the switching station. This outfit may be used to treat oil as it passes from the dirty to the clean oil tanks or it may be used to treat the oil in the circuit breaker tanks while the breakers are in service.

The switching station control building contains the relay equipment, storage batteries and charging equipment for operating the oil circuit breakers, store room, wash and locker room, and office.

Control cables between the switching station and the power plant are installed in a control tunnel. These cables are laid in trays supported by structural steel brackets along the sides of the tunnel. The trays are built of asbestos lumber reinforced with steel angles.

The high voltage circuits connecting the transformers at the power plant with the switching sta-

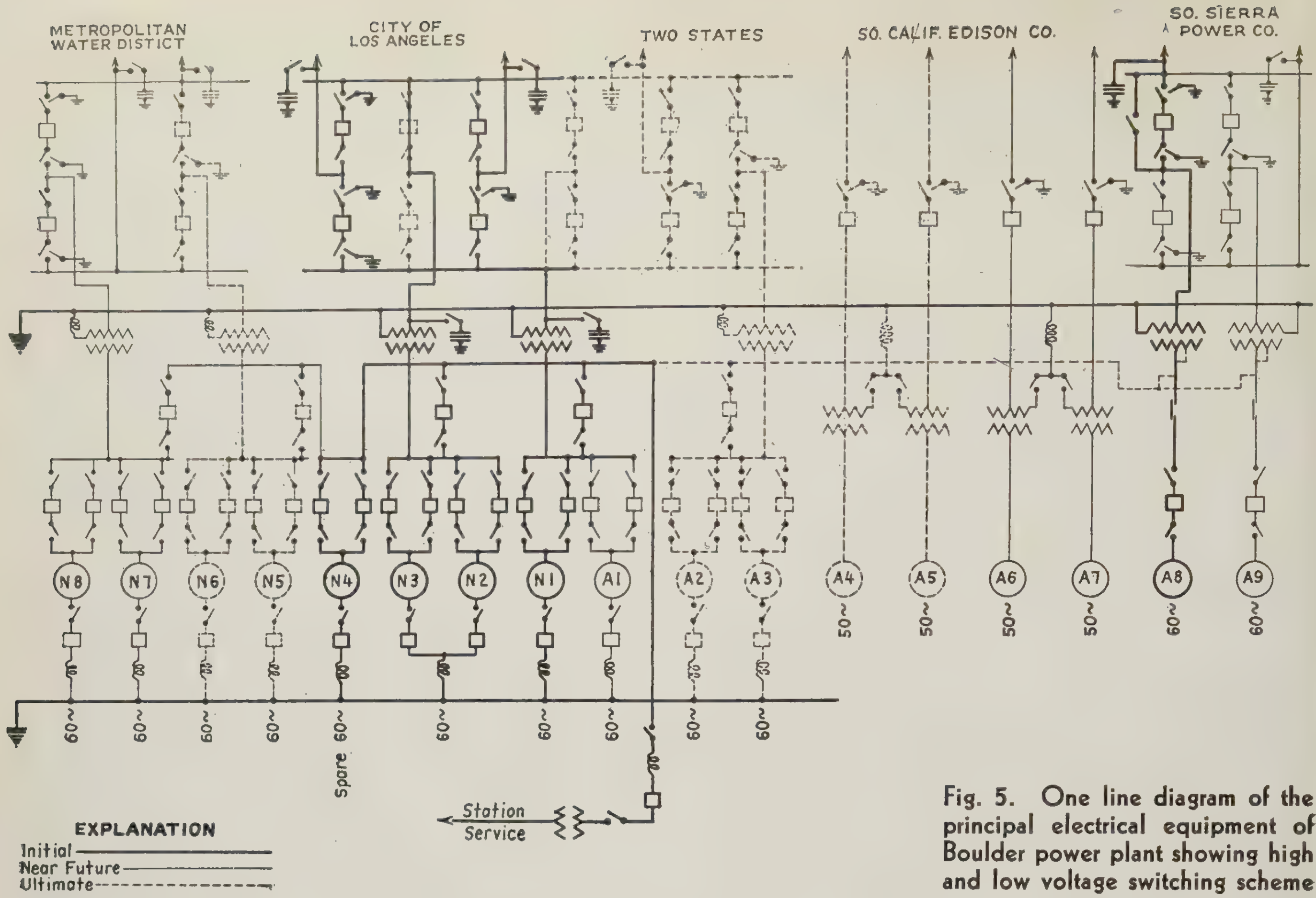

Fig. 5. One line diagram of the principal electrical equipment of Boulder power plant showing high and low voltage switching scheme

tion are supported on special steel towers. In order to keep the proper tension in the almost vertical spans from the power plant to the rim of the canyon the insulators at the lower ends of these spans are attached to cables which pass over sheaves and are attached to weights (see figure 3).

The towers at the rim of the canyon are inclined at an angle of 30 degrees from the vertical in order to afford sufficient clearance between the conductors and the cliff. The circuits between the power plant and the switching station are provided with overhead diverter wires supported on separate towers to shield the circuits from lightning.

Conductor spacing on the 287.5 kv circuits is 32 feet 6 inches, and the normal clearance to structures is 11 feet with a minimum of 8 feet. All spans have double strings of strain insulators at each end consisting of 22 units each with 6 inch spacing between units. Jumper loops are supported by suspension insulator strings with 24 units per string and 5 inch spacing between units. An automatic oscillograph is provided at the switching station for recording line and bus faults. Each outgoing transmission line is provided with a station type lightning arrester, and each circuit between the power plant and the switching station also is provided with a similar lightning arrester mounted on the power house roof to protect the main transformers. Each phase of each incoming transmission line has a coupling capacitor connected between conductor and ground for relaying and carrier current purposes.

Space available in the canyon between the dam and the 150 ton permanent cableway near the downstream end of the power plant is very limited for the high voltage circuits between the transformers and the switching station. This space limitation was one of the principle reasons for using a single bank of transformers for 2 main generators. Consideration was given to having a bank of transformers for each generator and eliminating all low voltage switching equipment and transfer bus; this arrangement, however, would have necessitated twice as many high voltage circuits between the transformers and the switching station as required by the adopted arrangement, and the space available was inadequate for the additional circuits.

Station Service Equipment

Two station service generating units, one in the upstream end of each wing of the power plant, provide power for all station auxiliaries. In addition, a bank of transformers is provided by means of which power for station auxiliaries may be obtained from the main generating units.

Each station service generating unit consists of a 3-phase horizontal a-c generator rated at 3,000 kva, 2,400 volts, 60 cycles, 300 rpm, with direct connected main exciter and pilot exciter, direct connected to a double overhung Pelton water wheel. Each Pelton wheel has a governor of the oil-pressure-relay valve type with individual motor driven oil pump and

pressure tank. Like the governors for the main units, the speed responsive elements of the station service governors are driven by electric motors receiving their power supply from small permanent magnet a-c generators direct connected to the main shafts of the station service generating units. The station service turbines receive water from a penstock which by means of valves may be connected to any one of the 4 main 30 foot penstocks. The station service penstock may be used to fill the main penstocks after they have been drained for inspection or maintenance purposes.

Station service generators as well as the bank of auxiliary power transformers are connected through oil circuit breakers to a 2,300 volt double bus from which all station auxiliaries, station lighting, and miscellaneous power loads are served. The 2,300 volt switching equipment is of the metal-clad vertical-lift draw-out type.

Station service load is divided into 2 groups. The first group comprises all equipment the operation of which is essential for the generation of power by the main units and includes the governor oil pumps, butterfly valve operating motors, and lubricating oil circulating pumps for the turbine and generator guide bearings. These essential auxiliaries are supplied with 440 volt power from 4 600 kva banks of transformers in the central section of the building. One bank of transformers supplies the essential auxiliaries for the even numbered generating units and a second bank the odd numbered units in the Nevada wing of the power plant; the other 2 banks are arranged in the same manner in the Arizona wing. Cross connections between the 2 440 volt busses permit all essential auxiliaries in each wing to be served from either bank of transformers so that each group of essential auxiliaries is provided with 2 independent sources of power.

The second group of station service auxiliaries comprises the less essential equipment the operation of which may be interrupted without interfering with the operation of the main generating units. This group includes the cranes, battery charging equipment, machine shop equipment, elevators, compressors, and other miscellaneous equipment. These nonessential auxiliaries are arranged in 2 groups each supplied with 440 volt power by a 600 kva bank of transformers in the central portion of the building. Cross connections permit all nonessential auxiliaries to be supplied from either bank of transformers. The general scheme for supplying power to the station auxiliaries is indicated by the single line wiring diagram shown in figure 6.

The 2,300 volt switching equipment is controlled and operated from a miniature control board in the main control room. The 440 volt control boards for the essential auxiliaries are located in the governor gallery adjacent to the turbines. This arrangement centralizes the control and operation of the butterfly valve, actuator, governor oil pumps, lubricating oil pumps, cooling water, and all other apparatus involved in the operation of a main generating unit at one point, except the electrical control of the generator which is handled by the switchboard operator in the control room.

Control Equipment

The Boulder power plant is divided into 2 distinct operating groups: One group consists of units *N*1 to *N*8 and *A*1 to *A*3 and the station service generating units, and will be operated by the Los Angeles Bureau of Power and Light; the other group consists of units *A*4 to *A*9, which will be operated by the Southern California Edison Company, Ltd. Control of the generating units, including the station service units and the switching equipment, is centralized in 2 control rooms on the top floor of the central section of the plant. Terminal boards are located on a floor below and directly beneath the control boards they serve, and the floor below the terminal boards serves as a distributing space for the control cables.

Main control boards are of the miniature type and provide for remote control of all main generating units and associated transformer banks, switching equipment, and outgoing transmission lines. Indicating instruments of the miniature type with 3 inch scales mounted on the vertical panels of the control board afford the operator all information needed for operating purposes. These indicating instruments include an ammeter, voltmeter, speed indicator, megavarmeter (mega-reactive-volt-ampere meter), and megawattmeter on each generator; 3 line ammeters, one for each phase; voltmeter and frequency meter for each line; megavarmeter, megawattmeter, and voltmeter for each bank of transformers; and gate limit stop and gate position indicator for each turbine. A group of annunciator drops for each unit is provided to indicate and call the operator's attention to any abnormal operating conditions.

The drops in the annunciator groups include the following:

Main generators	Main transformer banks
1. Low governor oil pressure	1. Excessive temperature
2. Hot main guide bearings	2. Cooling water failure
3. Cooler failure	3. Oil circulating pump failure
4. Excessive temperature	4. Excessive temperature in bus gallery or switch house
5. Differential relay operation	5. Transformer fire alarm
6. Overspeed	6. Differential relay operation
7. Excessive exciter voltage	7. Outgoing line relay operation
8. Overcurrent	8. Relief valve operation
9. High water in turbine pit	9. Gas pressure alarm
10. Ground on bus	10. 3 extra drops
11. 6 extra drops	

Should any abnormal operating condition be called to the switchboard operator's attention by the annunciator system, he can take the necessary steps to remove the cause by adjusting the controls, or he can call the matter to the attention of the generator or turbine floor man and instruct him as to proper procedure to correct the trouble.

Switches for controlling the operation of the various oil circuit breakers and disconnecting switches, with indicating lights to show the position of each breaker and disconnecting switch and a mimic bus showing the connections between the various electrical units, are mounted on the upper half of the in-

clined section of the control board. On the lower half of this section of the board are mounted the regulating controls which include control switch for generator regulator voltage adjusting rheostat, voltage control transfer switch, manual voltage control switch, butterfly valve operating control switch, governor speed adjusting control device, turbine wicket gate limit control switch, and governor speed droop control device.

The station service control board is also of the miniature type, similar to the main control board; it is located in the main control room of the Los Angeles Bureau of Power and Light. If necessary or desirable for any reason the main generating units as well as the station service units may be operated from local control stations adjacent to each unit and entirely independent of the main control board. Each generator has a control cubicle equipped with all necessary switches and instruments for starting, stopping, and controlling the operation of the unit, including control of the butterfly valve, actuator and generator oil circuit breakers. A key operated transfer switch serves to transfer the control of the generating unit from the main control board to the generator cubicle, or from the generator cubicle to the main control board. Transfer of control to one point renders control at the other point inoperable.

In addition to providing an emergency operating station for the generating units, the generator cubicles contain all relays, watt-hour meters, graphic meters, voltage regulator, and other equipment not required in the main control room. Each generator cubicle is equipped with a high-speed motor-operated rheostatic type of automatic voltage regulator which is provided with reactive compensator to equalize the wattless kilovolt-amperes between generators. Each transformer bank has a recording ammeter to record the current in the neutral. This instrument has 2 chart speeds, a slow speed for normal operation and a high speed which automatically comes into action when line-to-ground faults occur on the transmission lines.

Each main generator is provided with balanced differential relay protection. These relays have a characteristic with a 5 per cent slope, and they are interconnected with 3,000 to 5 ampere current transformers in the main generator leads balanced with 1,500 to 5 ampere current transformers in the neutral end of one half of each phase of the stator winding. This arrangement affords protection against faults to ground, faults between phases, and faults between turns. Operation of the differential relays opens the generator oil circuit breakers to isolate the generator from other sources of power, closes the turbine wicket gates, applies the generator air brakes, removes field excitation, opens the generator neutral oil circuit breaker, and admits carbon dioxide gas to the generator housing.

The main transformer banks are provided with differential relay protection similar to the generator differential relays except that the characteristic of the transformer relays has a 25 per cent slope. The 16.5 kv bus also is provided with high speed differential relay protection. Resistance temperature detectors are used to record the temperatures of bearings and generator stator windings, and to operate alarms and annunciator drops if the temperatures should exceed predetermined amounts. Thermometers with contacts are arranged to cause automatic shutdown of the unit if the temperature of the bearings becomes excessive.

A cable gallery running the full length of each wing of the power plant and across the central section immediately below the bus gallery provides space for the control cables between generating units and control room. The control cables are supported by asbestos-cement lumber trays arranged one above the other and supported by structural steel columns and brackets.

Auxiliary control boards in the main control rooms have recording instruments mounted on the front facing the operator's desks, and the automatic load and frequency control equipment is mounted on the rear. Multipoint recorders keep a record of the temperatures of bearings and transformers. The temperatures of the rotors of the main generators are recorded by single point Kelvin bridge type instruments which function by means of slip ring voltage and the voltage drop across a shunt in the rotor leads. Totalizing instruments record and totalize the outputs of the main generators by means of electrothermic load converters which deliver direct current output proportional to the kilowatts of generator output. These totalizing instruments are calibrated to record primary a-c output.

The automatic load and frequency control equipment is arranged so that any generator may be placed on frequency, base load, or proportionate load control. The frequency is corrected automatically whenever the deviation amounts to 0.01 cycle or more. Accumulated time errors are corrected automatically. Each auxiliary control board has an automatic synchronizer of the thermionic type for controlling the speed matching and synchronizing of the main and station service generators.

Clocks in the power plant, as well as all graphic charts, are operated by synchronous motors which receive their power supply from a special circuit, the frequency of which is controlled accurately by means of a special tuning fork and amplifier system operated from a storage battery. The tuning fork controls the frequency of 2 7.5-kva single-phase a-c generators driven by d-c motors. The speed of these inverted motor generator sets is controlled accurately by means of electron tubes which control the field excitation of the motors.

An automatic telephone switchboard in a telephone room in the central section of the power plant provides communication facilities throughout the plant and at various points on the dam and related structures. It has trunk connections with an automatic switchboard at Boulder City. There is also a cordless type manually operated telephone switchboard in each control room by means of which the operators can communicate with operating stations in the power plant. These cordless switchboards also will connect with trunk lines to Los Angeles, with the carrier current channels to the switching stations on the transmission lines, and with the terminal substations at Los Angeles. A code call

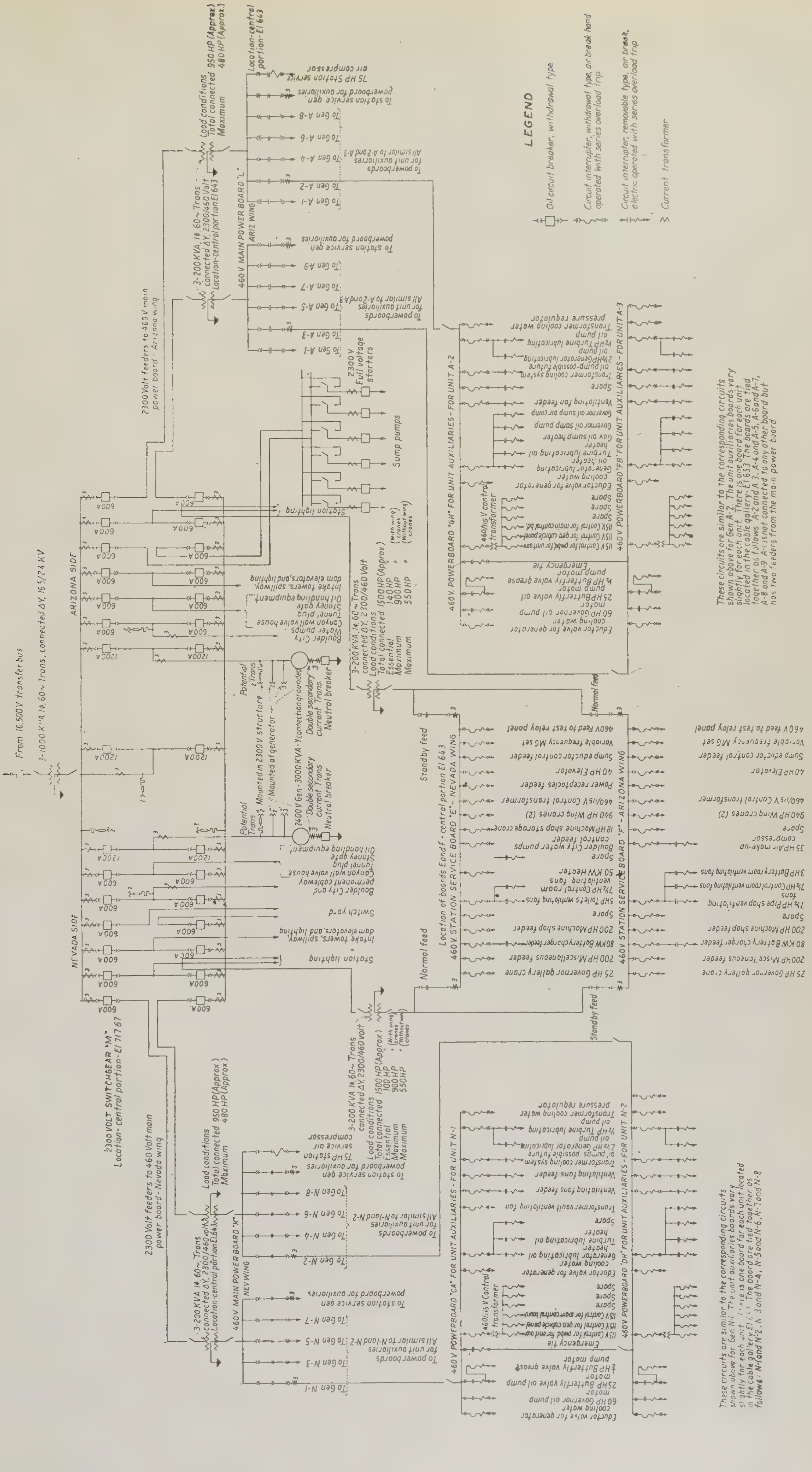

Fig. 6. Single line diagram of 2,300 and 460 volt station service and auxiliary feeders

system with bells at various points in the power plant and dam is incorporated in the automatic telephone equipment.

Two 120 cell storage batteries provide 250 volt d-c power for the operation of oil circuit breakers, lubricating oil pump motors, emergency lights, and other equipment in the wings of the power plant, and one 60 cell storage battery supplies 125 volt d-c power for the main control rooms. The storage batteries and their control boards and charging sets are located in a battery room in the central section of the building.

Lighting

Two 2,300 volt feeders from the 2,300 volt station service power busses supply the lighting circuits in both wings of the power house. At 4 points in each wing taps are taken from these lighting feeders through enclosed fused disconnecting switches of high rupturing capacity to single phase 2,300 to 230/115 volt lighting transformers. Each lighting transformer supplies the lighting for 2 bays, and alternate bays are supplied by different 2,300 volt feeders so that a failure of one feeder would affect only the lighting in alternate bays. A d-c lighting circuit supplied from the station storage battery is arranged to provide emergency lighting at essential points in the event of a complete failure of the a-c supply. The central portion of the building is supplied with lighting by means of 2 independent banks of transformers with provision for supplying the entire central portion from either bank in the event of a failure of the other bank.

D-C Circuit Breakers for Steel Mill Service

With several large motors and generators operating in parallel in a system that is coupled very closely electrically, short-circuit currents in d-c steel mill circuits may be as high as several hundred thousand amperes with a rate of rise of from 10 to 20 million amperes per second. Circuit breakers for this service therefore must have high current interrupting capacity and quick response. In this paper the circuit breakers and associated equipment for a typical modern strip mill are described. The circuit breakers are tripped not only by overload current, but also by current having too high a rate of rise.

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IN THE STEEL MILL, and particularly sheet and plate rolling mills, the loads are highly concentrated. In normal operation several large d-c motors are fed from generators operating in parallel in a system that is coupled very closely electrically. The generators, usually driven by synchronous motors, are built for inherently close voltage regulation, and this together with the effect of quick acting voltage regulators produces a very stiff system voltage. The motors driving the rolls are built to maintain their speeds within close limits over wide variations in load, for maintenance of proper relativity of speed between successive rolls is most necessary. Departure from proper relative speeds would result in intolerable stretching or accumulation of material between rolls. Changes in load on a motor then are reflected immediately in magnitude of current taken by the motor; a graph of motor load current shows extremely wide swings in intervals measured in microseconds. Because of the characteristics of the motors and their supply circuits, a motor in distress resulting from excessive load will attempt to carry on at its regular speed, even to the point of flashover. In the event of a flashover, not only the generators feed into the fault, but also all the motors, running by inertia, become generators and operate in parallel with the regular generators to feed a current into the fault which tends toward an enormous magnitude with an extremely high rate of rise.

For the foregoing reasons, therefore, the protective apparatus must respond quickly to critical conditions and be capable of interrupting currents of great magnitude; furthermore it must be arranged to function without incidental danger to life or property. The bus structure must be built to withstand the mechanical forces of the high currents, likewise the connections between motors and generators and bus. Indeed it may be even more important to give careful consideration to bracing the leads to motors and generators than most of the bus for the leads of a machine that flashes over must carry the total fault current. The leads of the other machines carry only their respective contributions to the total fault current, and the magnitude of the current in a particular part of the main bus depends upon the location of that part relative to the points of connection of the

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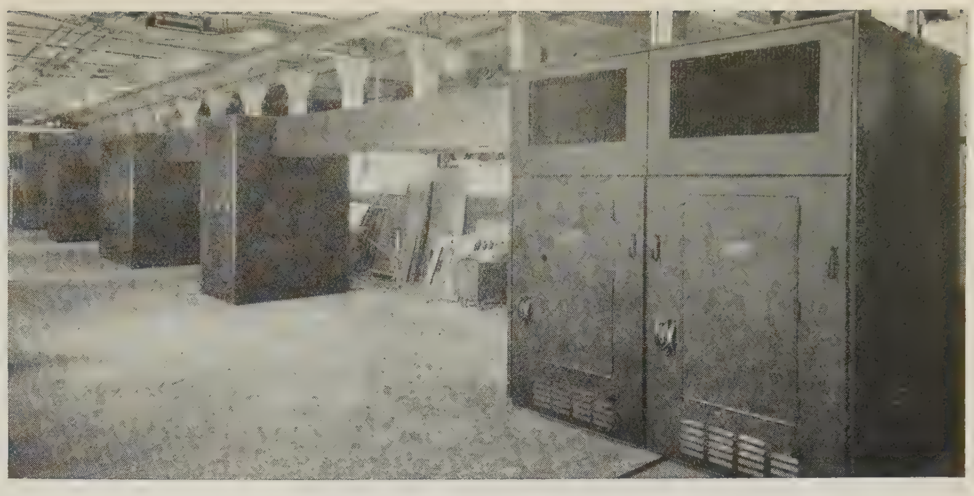
Fig. 1. Fully enclosed truck type circuit breaker equipment and associated enclosed bus structure for a typical modern strip mill



several machines and the point where the fault exists. Of course, should the motor connected to the end of the bus flash over, the bus to the motor leads, being in effect part of the leads, carries the same current as the leads and must be braced equally well.

A typical strip or plate mill involves 600-volt d-c motors of from 2,500 to 5,000 horsepower each and generators of 2,000 to 4,000 kw each. One such mill uses 5 or 6 such large motors for the main rolls, and 4 or 6 such generators; in addition, there are 1 or 2 smaller motors of about 500 horsepower each for the edgers. There is, therefore, generator capacity of the order of 16,000 kw, to which is connected a motor load of about the same magnitude. Consequently, there is somewhat more than 30,000 kw. of d-c rotating machinery operating at 600 volts, all closely coupled electrically on a bus having a total length of less than 100 feet. When a flashover occurs, a fault current magnitude of 5 or 6 hundred thousand amperes is quite within the realm of possibility as an ultimate value. Toward this value, the current tends at a very high rate of rise, governed largely by the combined inductances of the armatures. It is difficult to quote specific values for the rate of rise of current, but it is safe to say that the rise is at least of the order of 10 to 20 million amperes per second. Should the current actually reach these values, the mechanical forces on the busses and leads would be expressed in tons per foot of length.

Circuit Breakers for a Typical Strip Mill

In one of the most recent installations of strip mills, the protective circuit breakers for the motors and generators all are of the fully enclosed truck type, and the bus is built into, and thus is an integral part of, the complete assembly. Figure 1 is a view of the structure taken during factory assembly. The circuit breaker and bus assembly will be located in a gallery beneath the motor and generator room. The leads from the machines pass down through the floor of the motor room and into the respective circuit breaker cells of the structure. Those parts of the leads between the ceiling of the gallery and the tops of the circuit breaker cells will be suitably enclosed by rectangular sheet steel "pant-leg" arrangements. Each circuit breaker is located in the gallery as nearly as possible directly below its machine, motor or generator, and the main bus is carried horizontally between and through the groups of circuit breakers so located.

Referring to figure 1, at the far end is an assembly of 3 circuit breakers, one for the 500 horsepower edger motor, the middle one for a 3,000 horsepower motor, and the next for a 3,300 kw generator (consisting of 2 1,650-kw 300-volt units operating in series). A bus run connects this group with the next circuit breaker which is for a 3,000 horsepower motor alone. Next is a group of 2 circuit breakers, one for a 3,000 horsepower motor, the other for a generator similar to that just referred to. Next there is a single circuit breaker for one 3,000 horsepower motor. At the near end is a group of 2 circuit breakers, one for a 2,500 horsepower motor, the other for the third generator, which is similar to the other 2. The groups of circuit breaker cells and each of the bus runs between them are fabricated in the factory and are each shipped assembled complete in themselves; the installation thus consists only of erection of the several factory-assembled elements.

Figure 2 is a view of one of the cells with the side removed to show the manner of connection between the stationary male contacts in the cell and the bus above. The under side of the bus run enclosure was removed to show the bus as it runs between circuit breaker groups and through the cells. The leads to the machine from the circuit breaker are not shown in the figure, but the insulators that will support them and the terminals to which they will connect appear in the rear of the cell. In each cell provision is made for mounting a shunt for metering on that machine.

The circuit breakers, themselves, are all of the 2-pole air type, with 6,000 ampere rating for the motors and 8,000 ampere rating for the generators. Each is solenoid operated, with provision for hand operation from the outside of the truck. Each breaker also is equipped with special features, such as magnetic blowouts and rate-of-current-rise trip, in addition to instantaneous overcurrent trip and mechanism arranged for quick opening, which together particularly fit them for the service.

Figure 3 is a close-up of one pole of a breaker from which the arc chute was removed so as to show parts that otherwise would be hidden. The iron and the pole pieces of the blowout coil are shown mounted on the upper stationary terminal. The movable contact structure consists of a group of silver-faced laminated copper bridges as the main current carry-

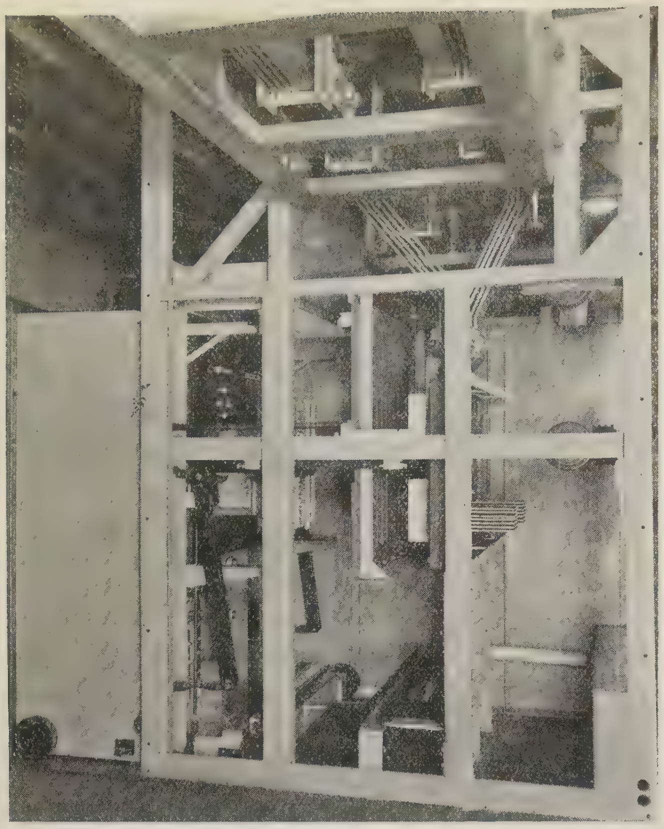


Fig. 2. One of the circuit breaker cells with side panel removed and truck partially withdrawn

ing member, a secondary contact, and an arcing contact. The secondary and the arcing contacts are carried by a stiff member, rigidly attached to the moving arm of the circuit breaker, so that in effect the mechanical forces incidental to operation of the breaker under high currents must serve only to accelerate the moving parts toward the fully open position. Deformation of the arm of the breaker is prevented effectively by the rigidity of construction of the member that carries the secondary and arcing contacts. These contacts are so pivoted and the current is led to them in such manner that the contact pressure between stationary and movable members of both secondary and arcing contacts is increased by the mechanical forces resulting from the magnetic action of the current. The great contact pressure thus developed accomplishes 2 purposes: The resistances of the paths through the secondary contact and through the arcing contact are reduced greatly so that the current is transferred more easily from the main current carrying member; and because both the auxiliary contacts are pivoted in a rigid extension of the main bridge arm, these same forces serve to accelerate the opening of the breaker. Thus the mechanical forces created by the current are used (1) to insure correct sequential operation of main, secondary, and arcing contacts, and (2) to cause faster opening action at high currents. The arcing contacts are of nonwelding alloy and open in the field of the iron blowout magnet, which is excited by a coil of copper worked into the stationary contact.

Response of a circuit breaker to an initiating condition is in 3 stages, which are, in reverse order; the time of arcing after the breaker contacts have opened effectively, the time taken by the breaker mechanism to open its contacts effectively after being unlatched, and the time to unlatch the breaker mechanism after conditions for opening the circuit are fulfilled. It has just been explained that the magnetic blowout reduces the time of arcing and that the breaker mechanism, already inherently fast, is speeded up further by the reactions of the mechanical forces created by the magnetic effect of the current; it remains to indicate how the interval to unlatch the breaker is reduced.

All breakers are tripped directly by a magnet acted upon by the main current. In order that there may be minimum hysteresis on rapidly changing current, both the tripping magnet and the armature are laminated; and to maintain at a minimum the mass to be accelerated, the armature is spring loaded and the air gap small—of the order of $^1/_4$ inch. When, therefore, conditions under which the breaker should unlatch are attained, a low-inertia moving member is caused to move through a short distance, to accomplish the result.

Fig. 3. Closeup of one pole of a 600-volt d-c breaker with arc chute removed

Rate-of-Current-Rise Tripping Feature

The tripping feature of the breaker responds not only to direct load current but also to the rate of rise of that current. When serious trouble occurs, the current rises very rapidly; and if the tripping depended upon magnitude of current only, the current might grow to dangerous proportions while the circuit is in process of being opened.

Figure 4 illustrates the manner in which rate of rise of current is combined with overcurrent as the criterion for tripping. The lower lead of each pole of the circuit breaker is divided into 2 parallel paths, one of which links with, and thus is the exciting means for, the tripping magnet. This is a path of higher resistance than the other. The other path is made of high inductance by the presence of closely stacked iron laminations. For a steady, unchanging current in the circuit, the total current will divide in

this lead according to the conductances of the 2 parallel paths. For a slowly rising current, substantially the same conditions obtain; thus if the slow growth continues, the circuit breaker will trip at a critical value of total current, according to the calibration. If, however, the current tends to rise with great rapidity, the inductance of the path that does not excite the tripping magnet becomes effective and a greater proportion of the total current is forced through the other (the trip-magnet-exciting) path. Thus the actual value of the total current may be less than the value at which the breaker is set to trip by calibration at steady currents, and the opening of the circuit breaker commences much earlier than if it were necessary to wait for the current to reach the steady-current-calibrated value.

Force acting on the tripping armature is great and continuous, in fact increases steadily, because of the growth of current and also because of the reduction of air gap; it does not depend upon an impulse, so the tripping is insured, and positive. The efficacy of the magnetic loading of the inductive member of the parallel arrangement depends, of course, upon the change of magnetic flux surrounding that member, not upon its absolute value. The continuous flow of current naturally tends to magnetize the choke iron; hence to avoid loss of sensitiveness resulting from saturation, air gaps are provided at top and bottom in the stack of choke iron. The amount of iron provided is adjusted to distinguish between allowable rates of rise of current such as occur in starting or in working changes in load and higher rates which indicate the existence of a fault. This relative action is adjusted by the length of the air gaps between the halves of the stack.

Thus, the breaker not only is tripped when the current increases to a particular value, but also by being sensitive to the rate of rise of current, and because the rate of rise is high in case of fault, the opening of the circuit is instituted at the beginning of trouble instead of waiting until it reaches a certain magnitude.

Main Bus

The main bus deserves a few words. Figure 5 is a view taken with the camera set upon the top of one of the circuit breaker cells and with the tops of the bus run enclosures removed. The cell in the center of the picture is the one shown in figure 2. The leads to the motor will pass upward through the opening in the rear of the top. Several different designs were considered for the main bus. Aluminum finally was chosen as the material, and a combination of one channel and several flat bars as the form. This form seemed to meet best the requirements of leads to the circuit breakers and to the machines. For other reasons the leads were of flat bar form, and the combination of flat bars and channel in the main bus afforded a most satisfactory manner of clamping; the channel gave necessary rigidity to the bus. The flat bars of the leads were clamped between the flat bars of the bus and between the near flat and the back of the channel.

Each bus is supported in special clamps carried by heavy porcelain insulators mounted horizontally, so that the insulators are subjected to compression by the mechanical forces on the busses caused by the current. Bus runs between groups of circuit breaker

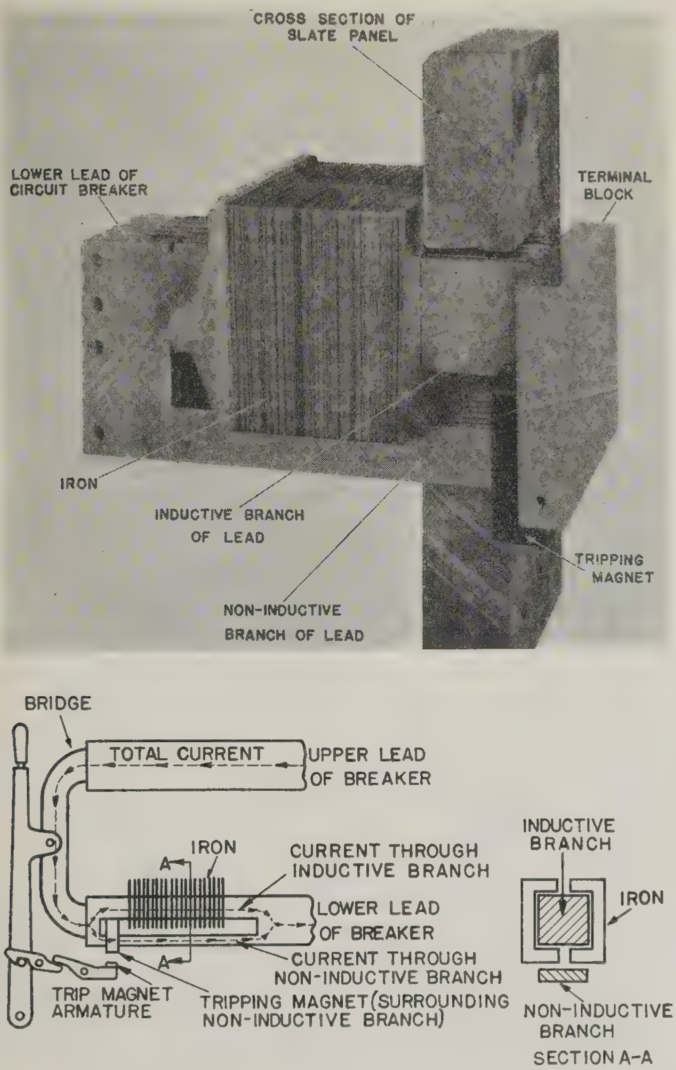


Fig. 4 (left). Details of lower lead of circuit breaker and diagram showing how rate-of-rise feature is incorporated in the breakers

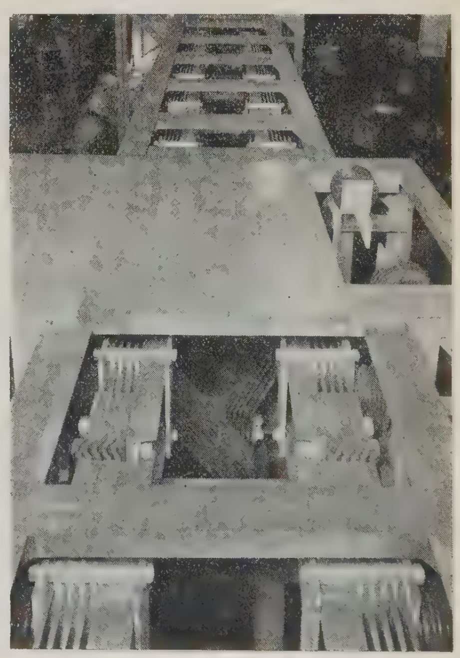


Fig. 5 (right). Top of bus structure with top of enclosure removed

Fig. 6. Steel enclosed circuit breaker board for controlling and distributing 440-volt a-c power in the mill

cells are supported by a deep steel channel on each side. These serve as sides of the enclosure and as supports. At frequent intervals along each bus run there is a ring welded of structural steel in turn welded to the side channels. These rings support the bus supporting insulators, and hence also take the repulsive forces between busses. The supporting insulators and the rings are spaced closely enough along the length of the bus run so that for heavy short-circuit currents the stresses in the busses are held safely below the elastic limit. At each group of circuit breaker cells, one end of the bus run to the next group is held rigidly to avoid lateral forces on circuit breaker and machine leads, and at the opposite end of each bus run an expansion joint is provided. The top and bottom of the bus runs are covered with sheet steel in which are protected openings for ventilation. The enclosed bus has a nominal rating of 10,000 amperes. Short sections of the bus were mounted in each circuit breaker group making it possible to assemble all such groups and all bus runs in the factory. Each was shipped without disassembly, completely fabricated in itself and ready for installation in the field.

The whole assembly is about 91 feet long, consisting of 5 groups of circuit breakers and the 4 interconnecting bus runs. It is planned that at some later date a unit will be added to the group of 3 circuit breakers shown at the far end in figure 1, and the bus and the structure itself are arranged for making this change conveniently.

440-Volt A-C System

For controlling and distributing the 440-volt a-c power in the mill, a steel enclosed circuit breaker board illustrated in figure 6 was furnished. Each of 2 3,000-kva 13,800 460-volt 3-phase transformers feeds through aluminum channels arranged in pairs to a 4,000-ampere 3-pole circuit breaker in the board. From each of these circuit breakers aluminum channel busses extend toward respective ends of the board, and at each end individual circuits are taken care of by 1,250-ampere 3-pole breakers. In the center a 3,000-ampere 3-pole bus-tie breaker is provided, and on one side, in addition to the smaller breakers, a 2,000 ampere feeder breaker is built into the board. In the corresponding space on the other side a fully equipped cell is built in so that in the future, a 2,000 ampere feeder breaker may be added to the equipment.

All circuit breakers of 2,000 ampere and higher capacity are of the truck type and are of a design similar in general to those described for the 600 volt d-c assembly, except, of course, that they do not have the rate-of-current-rise feature. The 1,250 ampere breakers each are mounted in separate compartments and are carried on a pantograph structure. Thus they have many of the features of the truck type breakers, such as convenience of removal, provision for test position, separable contacts, etc. All circuit breakers are solenoid operated, and except for the bus tie breaker they are equipped so that they will reclose automatically 3 times upon being tripped on overload and then lock open.

250-Volt D-C System

The board for the 250-volt d-c system is similar in general design to that for the 440-volt a-c system in that it is a compact arrangement of circuit breakers protecting incoming and outgoing circuits. A breaker for each generator and for each feeder is provided, and all are completely bussed together in the structure. Each feeder is protected by a 3,000-ampere 2-pole breaker. Each generator feeds into the board through a circuit breaker having 2 8,000 ampere and 1 4,000 ampere poles, the latter for the equalizer circuit. The feeder breakers have a dual overload trip, which gives time delay on small overloads and instantaneous action on high currents. The generator breakers have instantaneous overload trips with rate-of-current-rise feature on all poles, including that for the equalizer.

All breakers are of the truck type similar to those used for the 600-volt d-c system. The cells are assembled into one unit and a bus runs the length of the board. In this case, space was of importance rather than weight, and copper was chosen as the material for the bus. In form each bus consists of a copper channel in combination with flat copper bars, forming a bus similar to that described for the 600-volt d-c board. The same form of bus was used also for the equalizer. The positive and negative busses are rated at 15,000 amperes and consist of an 8-inch copper channel combined with copper bars $^3/_8$ inch thick. The equalizer bus was built of a 4 inch copper channel combined with flat bars. Each bus is supported by heavy insulators similar to those used for the 600-volt d-c bus, and in general the insulators are subjected to compression by the repulsive force between the positive and negative busses. Between the positive and equalizer busses strain insulators are used to avoid cantilever loading on the supports of either.

In each cell, a shunt is mounted, to be used for metering. The board is 73 feet long and includes 18 feeder and 5 generator breakers. The generator connections are flat copper and enter the board through the top from the floor above. Feeder conductors are multiple cables and leave the board through the floor in conduits.

Transient Voltages in Rotating Machines

The unequal distribution of voltage in rotating machine multiturn coils caused by switching transients, and means for alleviating the stresses occasioned by these transients, are discussed in this paper. A brief description also is given of field measurements of switching transients and of tests to determine the effectiveness of capacitors as a protection against switching transients. It is shown that capacitors connected between each phase and ground near the machine terminals gives effective protection.

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THE present trend in the application of a-c motors is to eliminate all reduced voltage starting equipment by using motors that are suitable for full voltage starting, because the amount of equipment necessary for a given installation is reduced. Also, some water wheel generators, especially those in automatic and semi-automatic stations, are arranged to be started by being brought up to nearly synchronous speed, and then, without excitation, switched onto a line bus; this method of starting permits the generator to be placed in service quickly without the formality of synchronizing. Obviously, with either of these 2 methods of starting, the electrical stresses in a machine subjected to full voltage during the starting period are higher than those in machines started at reduced voltage or synchronized, because of the higher applied voltage.

The data described in this paper show that full voltage switching or the sudden application of line voltage to a machine winding produces a transient voltage across the first line terminal coil that is frequently of the order of 70 per cent of the crest of the line-to-neutral voltage. This results in high transient voltages across some of the turns of the winding. Insulation failures may occur unless the machines are either insulated for or protected from these transient voltages. Protection may be secured by connecting capacitors of the order of 0.1 microfarad or more between each phase and ground on the machine side of the circuit breaker which connects the machine to the line. These capacitors slope the wave front of the transient to a value which is safe for the turn insulation.

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General Considerations

The sudden application of rated voltage to an unexcited machine, such as takes place on all machines subjected to full voltage starting, produces a switching transient which causes an initial unequal voltage distribution throughout the winding. Most of the voltage is concentrated across the line terminal coils. Consequently, the transient voltage appearing across the first turn in a line terminal coil is much higher than the normal turn voltage. Since the turn stresses in machines started at full voltage are higher than in machines started at reduced voltage, it is clear that if equal performance and reliability are to be realized, either more turn insulation is required or protective equipment must be used to reduce the switching transients to safe values.

Cathode ray oscillograph measurements, to be described later, show that the magnitude of the switching transients which occur during the starting period is of the order of the crest of the normal frequency line-to-neutral voltage and so they should have little deleterious effect on the insulation between the conductors and ground. These measurements indicate also that the transients have very steep wave fronts.

Now it is a fundamental fact that all machine windings have inherent capacity both between turns and from the turns to the sides of the slot. This capacity is small and can be neglected at normal frequencies but must be considered at the higher frequencies. The impact of a steep front switching transient against a machine winding, with a crest equal to the crest of the normal line-to-neutral voltage, causes charging current to flow in these capacities. This charging current produces relatively high turn voltages especially in the line terminal coils. The voltage distribution between the turns in the terminal coils is not uniform, the highest voltage occurring across the first turn. The turn voltages become progressively smaller away from the line terminals because of the rapid attentuation and reduction of front of the switching transient as it travels into the machine winding.

Tests to determine the adequacy of turn insulation of a machine winding have never been the subject of national standardization such as has been true of the major insulation by standardizing groups like the A.I.E.E. and National Electric Manufacturers Association. The turn insulation must have considerable strength for mechanical reasons and, as the normal volts per turn are usually low, it can withstand the normal voltage easily. However, when it is considered that a switching transient may produce a potential difference between turns from 10 to 100 times the normal turn voltage, it is appreciated that special consideration must be given to the turn insulation in machines subjected to full voltage during the starting period.

The maximum line-to-ground transient voltage recorded in the tests to be described was approximately equal to the crest of the applied 60 cycle line-to-neutral voltage. The maximum transient voltage across the first line terminal coil was a little less than the measured transient line-to-ground voltage and, therefore, the electrical requirements for the turn insulation should logically be based upon the normal line-to-neutral voltage rather than the normal turn voltage. However, the space available for insulation in a machine is usually limited. It is the common practice today to supply the same grade of insulation throughout a winding. Since the transient high turn voltages are all located in the line terminal coils, it may prove to be more economical to insulate for these transient voltages in the line terminal coils only, the additional space for this insulation being obtained by having one less turn in these coils. This suggested procedure has one disadvantage in that coils with different numbers of turns are used in the machine, so that care must be taken in assembling the winding or in making coil replacements to assure that the correct coils are used; otherwise there will be high circulating currents.

For those cases where it is uneconomical to insulate for the maximum turn voltages which may be encountered in service, it is fitting to examine what devices are available for protecting a machine from switching transients.

Any discussion of protection against the effects of transient voltages immediately suggests lightning arresters. A lightning arrester is effective in reducing the magnitude of transient voltages but it

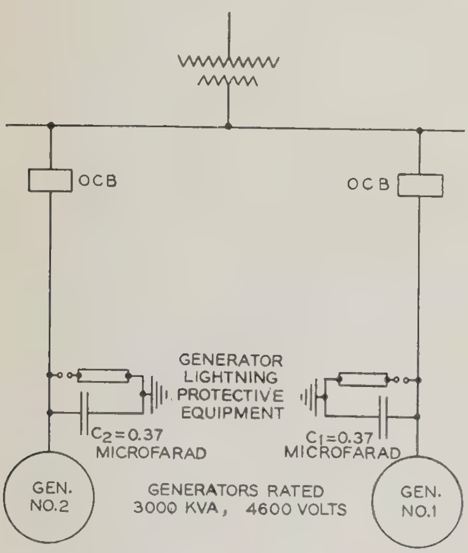


Fig. 1. One line diagram of station in which switching transients were measured

has little or no effect on the wave front. Also, an arrester cannot even reduce the magnitude of the voltage, unless the voltage exceeds the normal system voltage by some margin, because the arrester must be set to operate above normal voltage; otherwise it will function continuously and be destroyed. Since the switching transients do not exceed the crest of the normal line-to-neutral voltages, the arrester is not applicable.

The capacitor, on the other hand, is an absorbing device for transient voltages and because of this property, it can alter the front of the switching transient. Because it is the high turn voltages resulting from steep wave fronts which may damage the turn insulation, the capacitor appears to be a

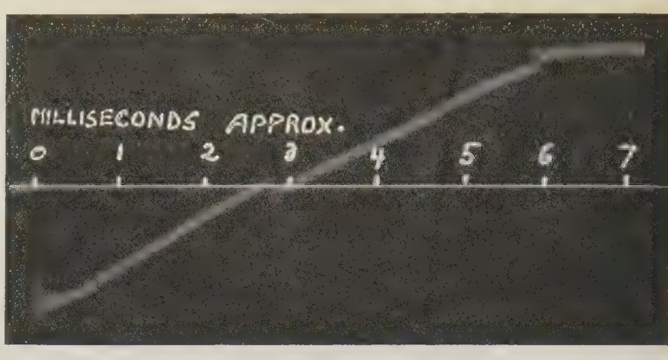


Fig. 2. Cathode ray oscillogram of terminal line-to-ground voltage at the instant of switching the unexcited generator onto the bus

suitable device for protecting a machine winding against switching transients. An arrester is needed with the capacitor only when there is a possibility of resonant voltages.

There is still much to learn regarding these transient voltages and their effect on the insulation commonly used between turns in machine windings. A machine apparently does not fail the first time it is subjected to one of these transient voltages. Both voltage and time are necessary to cause an insulation breakdown, since energy is required. Should the turn insulation in a machine become punctured, it is probable that on account of the very short duration of these transients and the low normal turn voltages, the gap in the insulation would not remain ionized for a sufficient time to permit the establishment of short-circuit current, with the result that the insulation could be punctured many times before the damage resulted in a short circuit. Also, the number of times a machine winding is subjected to these transient voltages depends directly upon how often the machine is started. Thus, it is possible that a machine with insufficient turn insulation for full voltage starting duty may operate for a long period, possibly several years, before a total breakdown of the insulation occurs.

Field Tests of Voltage Transients

A one line diagram of the station in which the switching transients were measured, showing the arrangement of the machines and oil circuit breakers, is given in figure 1. The machine under test was a water wheel generator rated 3,000 kva, 4,600 volts, 60 cycles. There were approximately 35 feet of single conductor cable between the machine and the 4,600 volt bus with the oil circuit breaker located adjacent to the bus. The "self-synchronizing" method of starting was used to connect this generator to the system, i. e., the generator was brought up to 96 per

cent of normal speed by the water wheel under governor control and at this speed the generator was connected to the line unexcited. Excitation was applied to the field of the generator a few cycles after the oil circuit breaker was closed. This was the normal method of starting.

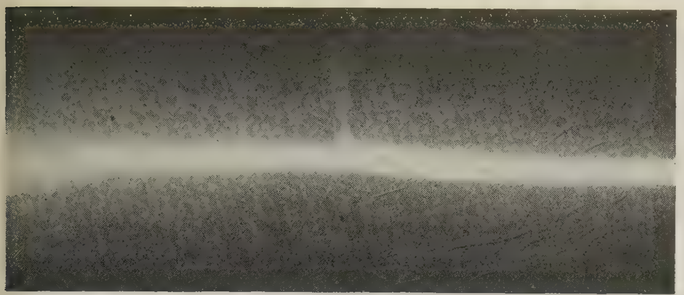


Fig. 3. Cathode ray oscillogram of the terminal coil transient voltage at the instant of switching the unexcited generator onto the bus

Crest of transient equals 2,600 volts

Cathode ray oscillograms were obtained of the magnitude of the transient voltages occurring from one machine terminal to ground and across the first line terminal coil. The oscillograph was timed to trip so that the record included the instant the oil circuit breaker first made contact during the starting period. No change was made in the normal starting sequence except that the arcing contact on the oil circuit breaker pole on the phase to which the oscillograph was connected was adjusted to insure that this phase would be energized first.

The wave shape of the transient coil voltages was not taken because its importance was not considered sufficient to warrant the extra complications to the testing equipment necessary to co-ordinate the closing of the oil circuit breaker and the tripping of the cathode ray oscillograph to obtain a record of the transient coil voltage, which lasted probably not over 10 microseconds.

The oil circuit breaker was not adjusted to close at any particular point on the 60 cycle voltage wave and as might be expected on these tests, it was just a matter of chance as to where contact would first be made. The tests indicated that 1 out of 6 oil circuit breaker closings would result in contact near the peak of the wave on any one phase.

In general, the tests were conducted so as to obtain as true a record as possible of the transient voltages as they occur during normal system operation.

The terminal line-to-ground voltage at the instant the oil circuit breaker made contact near the peak of the 60 cycle voltage wave is shown by the cathode ray oscillogram of figure 2. The wave appears not unlike a 60 cycle cosine wave with a superimposed damped sine wave oscillation on its crest. The 2 discontinuities on this curve were caused by the closing of the oil circuit breaker contacts on the other 2 phases. The frequency of the oscillation correlates with the natural frequency of certain of the known system constants. The sweep of the oscillograph for this test was approximately 7,000 microseconds. With this timing, the front of the wave appears to rise vertically.

The maximum transient voltage measured across the first line terminal coil is shown by the cathode ray oscillogram of figure 3. This transient voltage has a crest of 2,600 volts and a duration which is estimated to be less than 10 microseconds. It was caused by the rapid rise of the applied voltage and is not to be confused as being associated with the superimposed damped sine wave oscillation on the crest of the wave shown on figure 2. This superimposed oscillation has a frequency of about 7,000 cycles per second and hence for all practical purposes, the first terminal coil transient was over before this oscillation got under way.

Since the generator under test had 42 armature coils per phase per circuit, the first terminal coil is only 2.4 per cent of the winding. The crest of the rated line-to-neutral voltage of the generator was $4{,}600 \times \sqrt{2}/\sqrt{3} = 3{,}760$ volts, and each coil with a uniform distribution of voltage throughout the machine winding would have 90 volts crest across it. The measured transient voltage across this coil was 2,600 volts crest. Thus, 70 per cent of the line to neutral voltage appeared across 2.4 per cent of the winding.

Each armature coil had 4 turns and the normal voltage per turn was 22.5 volts crest. Since it was not feasible to measure the turn voltages, they could only be estimated. A uniform transient voltage distribution across the turns of the terminal coil would result in 650 volts per turn. Actually, it is known from laboratory tests on other machines that this voltage distribution is not uniform and that a larger proportion of the total transient coil voltage appears across the first turn. It is estimated that approximately 1,300 volts actually appeared across the first turn. This is 58 times the normal volts per turn.

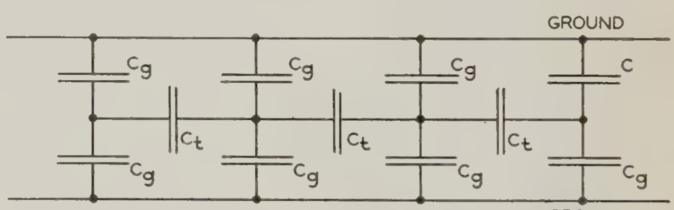


Fig. 4. Equivalent condenser network for a 4 turn coil in a rotating machine

The turn insulation on this generator had a strength which, based upon previous tests of insulation, was estimated to be above the crest of the line-to-neutral voltage and consequently was sufficient for these switching transients.

Effectiveness of Capacitors for Reducing Switching Transients

As the stresses in the line terminal turn insulation were caused by the steep front switching transients, tests were made with capacitors connected from line

to ground and located between the generator and the oil circuit breaker to obtain a measure of the ability of a capacitor to slope off the front of the transients. Part of the lightning protective equipment on this generator consisted of single phase capacitors having 0.37 microfarad per phase. With these capacitors in the circuit, the first terminal coil transient was reduced from 2,600 volts to 675 volts. This capacitor sloped off the front of the switching transient and produced a more nearly uniform initial voltage

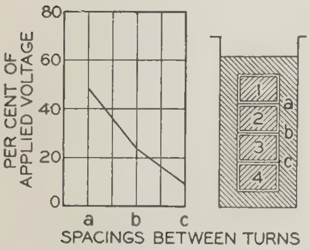


Fig. 5. Initial transient voltage distribution between turns of a 4 turn coil

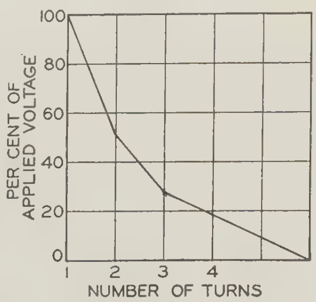


Fig. 6. Initial transient voltage distribution through a 4 turn coil

distribution throughout the generator winding, which resulted in less voltage across the line terminal coils.

The effectiveness of the capacitor in reducing steep wave fronts depends upon its size (microfarads) and also upon the surge impedance through which the transient must pass. For most applications, the capacitors probably need not exceed 0.1 microfarads, although the larger the capacitor is, the lower the line terminal turn voltages are likely to be. However, capacitors should not be used without first considering the circuit to which they are being installed because a shunt capacitance to ground is a possible source of resonant overvoltages. These overvoltages may constitute a greater hazard than the one the capacitor has been installed to protect against. When there is a possibility of resonant overvoltage, arresters should be used in parallel with the capacitors.

The location of the capacitors in the circuit is also important. To be effective, the capacitors must be installed on the machine side of the switch.

Appendix I—Maximum Initial Voltage Distribution Across Turns in First Line Terminal Coil

An approximation of the initial distribution of voltage resulting from the impact of a steep wave front transient on a rotating machine may be obtained from the capacitance network of the slot portion of a line terminal coil. This network consists of series capacitance between the turns and shunt capacitance from the turns to the sides of the slot.

The cross section of a 4 turn coil side in a slot, showing the arrangement of the turns and the turn and coil insulation is given in figure 5. It is to be noted that the insulation between the turns and that between each turn and the sides of the slot comprise the dielectrics for condensers whose plates are made up from the surfaces of the turns adjacent to each other and the sides of the slot. The capacitances of these condensers may be obtained from the formula for a parallel plate condenser. The equivalent condenser network for a rotating machine winding consisting of a 4 turn coil is shown in figure 4. Two methods for reducing this capacitance network so that the distribution of voltage may be obtained are available:

1. By determining the current in the different branches of the network, either from a longhand or a d-c calculating table study, and estimating the voltage distribution from these currents.
2. By determining the equivalent capacity of the network $C_0 = \sqrt{2C_gC_t}\tanh n\sqrt{\frac{2C_g}{C_t}}$ (where n = number of turns) and the voltage across a turn as the ratio $\frac{C_0}{C_t + C_0}$ of the applied voltage.

Curves have been prepared to show the initial voltage distribution through a 4 turn coil and also between turns, for a coil in which the thickness of the coil insulation is 8 times the thickness of the turn insulation. These curves are shown in figures 5 and 6, and indicate that a nonuniform distribution of voltage initially exists across the coil, with the highest turn voltages occurring between the first and second turns.

Appendix II—The Effects of Capacitors Connected to the Bus

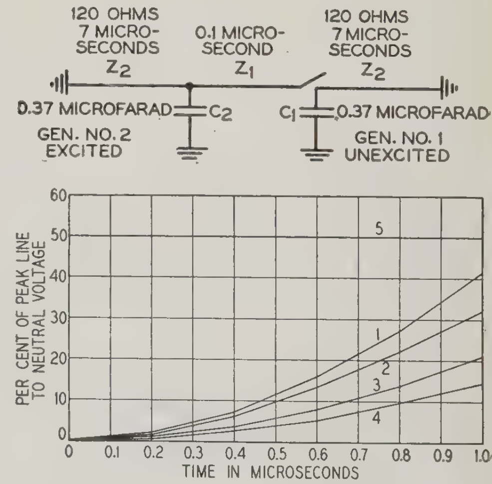
Capacitors which are used for lightning protection purposes are connected from line to ground and are often located on the system rather than the machine side of the oil circuit breaker. With the capacitors in this location they may be charged to full system voltage and they will discharge into the unexcited machine when the switch is closed. As this may occur on some one phase of the winding, each time the switch is closed, it is conceivable that it might be a greater hazard than the lightning transient against which the capacitors are intended to protect. Some data were obtained on this subject during the test previously described.

Referring to figure 1, both number 1 and number 2 machines have 0.37 microfarad capacitors on their terminals. Transient voltages across the first turn of number 1 machine unprotected by capacitors were measured with the cathode ray oscillograph with and without the number 2 capacitor and generator in service. No increase in the terminal coil transient voltage was found with the number 2 capacitor and generator in service. This was due to the fact that the surge impedance of the cable between the capacitors was sufficient to limit the rise of the voltage on number 1 generator.

A theoretical study of this rate of voltage rise, with capacitors on both machines, for the first microsecond after the switch was closed

Fig. 7. Voltage rise on unexcited number 1 generator when switched onto the bus

1. Z_1 = 60 ohms surge impedance
2. Z_1 = 45 ohms surge impedance
3. Z_1 = 30 ohms surge impedance
4. Z_1 = 0.0172 millihenrys inductance
5. Z_1 = 0.0074 ohms resistance



is shown on figure 7. The distance between the capacitors has been taken as 0.1 microsecond, and the voltage rise for several values of surge impedance of the cable have been worked out. Curves are also given as a matter of interest for the voltage rise by assuming the tie between the capacitors to consist of resistance of 0.0074 ohms and also of inductance of 0.0172 millihenrys, which were the resistance and reactance values of the cable.

These curves show that the rate of voltage rise is a function of the surge impedance and the length of the cable between the 2 capaci-

tors and that the build-up of voltage does not progress very far in one microsecond even for a cable with a length of 0.1 microsecond. These theoretical and test studies did not indicate anything from which it might be concluded that the capacitors increased the switching hazard, but on the contrary, the tests showed that the capacitors reduced the switching transients to safe values.

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D-C Cleanup in Insulating Oils

Three unusual types of behavior of insulating oils have been subjected to a series of experiments which indicate that all 3 are closely related. These types of behavior are the reduction of conductivity and a-c dielectric loss following a sustained application of continuous potential (called "d-c cleanup"), the current-time relation under continuous potential, and the unequal potential distribution under continuous stress due to the accumulation of space charges toward the electrodes. Theories regarding a common cause of these different types of behavior are drawn from the experiments.

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All highly insulating or dielectric liquids show some residual conduction and dielectric loss. After careful purification by successive redistillation and other methods, a very low figure of conductivity may be reached (10^{-18} mhos per cubic centimeter) and, in its volt-ampere characteristic, the liquid shows a definite saturation region followed by an up-turn at higher values of voltage gradient. This has suggested a behavior similar to that of gases, and a corresponding theory of ionic conduction corresponding to that for gases has been proposed and is sustained with substantial evidence.[1] However, even in these cases under alternating stress the dielectric loss is not accounted for by the final steady state conductivity and the complete explanation of this loss is not to be found in the simple theory mentioned.

The very pure liquids referred to in the foregoing paragraph are not available for insulating purposes by reason of the costly and elaborate processes necessary for purification and the impossibility of maintaining such purification. On the other hand, the insulating oils of practice, derived largely from the petroleum crudes, do attain in the process of refinement a very advanced state of purification and have a very high level of insulating characteristics. Final conductivities of the order of 10^{-10} to 10^{-16} mhos per cubic centimeter may be well maintained if the oil is protected from oxidation and other contamination. However, the electrical behavior of these oils is even more highly anomalous and the problem of theoretical explanation is correspondingly complex. This is largely due to the variety of phenomena exhibited and the plurality of suggestions in explanation. Among such explanations are electrolytic conduction due to dissociated impurities, inherent dissociation of the liquid molecule itself, dissociated organic acids due to oxidation, polar properties of molecules or molecular aggregates, and the like. Each of these phenomena is suggested by the behavior in particular cases or conditions but the picture often changes as the whole range of anomalous behavior is explored.

The purpose of this paper is to report a series of experiments which show that 3 types of anomalous behavior of insulating oils are closely related to each other and to throw some light on the nature of their ultimate common cause. The first of these is the so-called "d-c cleanup" of an insulating liquid, which is the progressive decrease in dielectric loss under alternating stress following a sustained application of continuous potential difference. This phenomenon has long been known. It was noted by Jaffé[2] in 1909, who attributed it to the gradual removal of electrolytic ions, and has recently been studied by Jackson[3] as related to the losses at high frequencies. The second phenomenon is the current-time relation

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1. For all numbered references see list at end of paper.

under continuous potential. The steady decay of current with time in an insulating liquid has also long been known, but the phenomenon seems to be governed by no definite law. In particular, one of the authors[4] has shown that the current-time curve, if observed sufficiently close to the instant of application of continuous potential, may have 3 regions of different types, suggesting a corresponding number of different phenomena. The third type of behavior here studied is that of the unequal potential distribution[5] under continuous stress due, as shown also by one of the authors and his co-workers,[6] to the accumulation of space charges toward the electrodes.

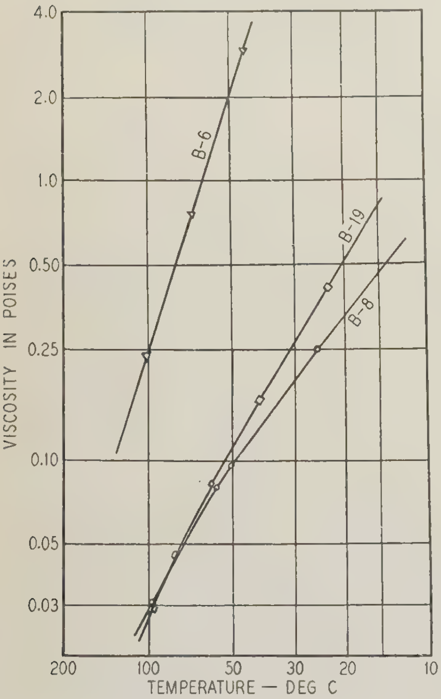

Fig. 1. Viscosity-temperature characteristics of 3 different oils

Oils B-6, B-8, and B-19

Table I—Physical Properties of Oil Samples

Oil No.	Base	Spec. Gravity 45 deg C	Flash Point deg C	Pour Point deg C	Surface Tension 45 deg C	Viscosity —Poises 45 deg C	Break down-Voltage Kv
B-6	Undewaxed paraffin	0.879	274	− 2	48	2.95	27.9
B-8	Refined water-white oil	0.824	139	0	32	0.112	31.1
B-19	Refined thin oil	0.877	149	−29	27	0.133	28.6

The Oils

Three different oils have been studied, of characteristics as shown in table I and figure 1. Two of these oils, *B*-6 and *B*-19, are commercial cable impregnants, the former for the so-called "solid," and the latter for the "oil filled" type of cable. The third oil, *B*-8, is of the same general type as that of *B*-19, except as regards the pour point temperature. Both these oils are thin highly refined liquids; the samples had suffered a slight deterioration during their storage life. Other properties of these oils have been reported elsewhere.[7]

The Measurements

Continuous records of both charge and discharge currents beginning 0.001 second after the application of voltage, were made with the amplifier oscillograph.[8] Beyond the range of the film of the oscillograph the record was picked up with a high sensitivity d'Arsonval galvanometer. The maximum sensitivity of the oscillograph was 1.7×10^{-8}, while that of the galvanometer was 3×10^{-12} amperes per millimeter.

Power factor or phase difference under alternating stress (60 cycles) was measured with a shielded Schering bridge capable of reading power factor to 0.000005. The test cell is a circular plate guard ring condenser. The measuring electrode is 52.7 centimeters in diameter. Provision is made for varying the distance of plate separation within the range of 4 to 10 millimeters. The whole cell is enclosed for thermal insulation and is provided with electric heat control and temperature measurement. The condenser is that used by Whitehead and Marvin,[6] modified, however, by enclosure of the cell in a gas-tight box which was kept filled with nitrogen before and after the oil was introduced so as to protect the latter from oxidation during the experiments.

The d-c cleanup was studied by applying constant values of continuous voltage within the range 500 to 1,500 volts and over the temperature range of 30 degrees to 80 degrees centigrade. At intervals of time the continuous stress was interrupted sufficiently long to measure the phase difference and loss. After approximately steady state was reached, the continuous potential was removed and the subsequent changes in phase difference were studied under both open-circuit and short-circuit conditions.

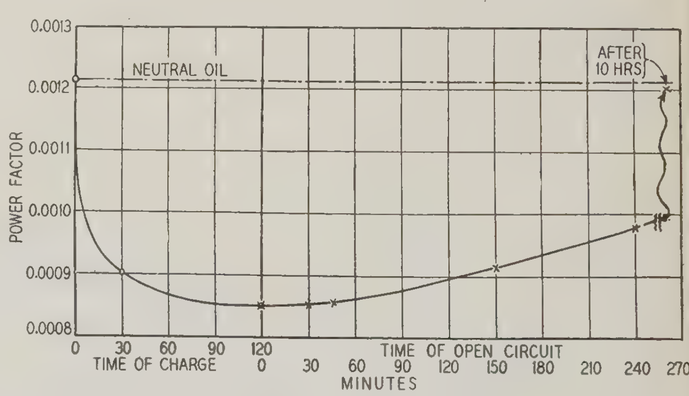

Fig. 2. Cleanup and recovery on open circuit

Oil B-6, at 500 volts direct current, and 45 degrees centigrade

The d-c current-time curves were taken for the corresponding ranges of potential gradient and temperature.

The space charge behavior was studied principally through observations on the current-time curve attendant upon reversal of continuous voltage following the long-time application of the opposite value

of voltage. As shown by Whitehead and Marvin[6] this phenomenon is related to the unequal potential distribution associated with space charge accumulation.

Results—
D-C Cleanup

Typical examples from a large number of observations on d-c cleanup and subsequent recovery are shown in figures 2, 3, 4, and 5. Figure 2 indicates a decrease of about 30 per cent in the value of phase difference in the steady state reached after 2 hours at 500 volts. Thereafter, with the condenser on open circuit, a slow recovery takes place, the original value of power factor being reached again after about 10 hours. Figure 3 gives a more comprehensive picture on the same oil at a higher temperature and higher voltage. Under the increased stress and diminished viscosity, the cleanup process is initially more rapid and the over-all improvement very much greater. The lowest value of phase difference reached in the 2 cases is, however, about the same. This figure also shows the difference in behavior in the recovery period as between open and short-circuit conditions. Recovery under short circuit is roughly twice as fast as under open circuit. Two curves for oil B-8 are shown in figures 4 and 5. These figures show the higher rate at which cleanup takes place under the higher stress but show apparently a lower over-all cleanup at the higher than at the lower voltage.

Exact duplications of d-c cleanup curves are difficult to obtain. The whole process seems to be very sensitive to the foregoing history of the specimen as

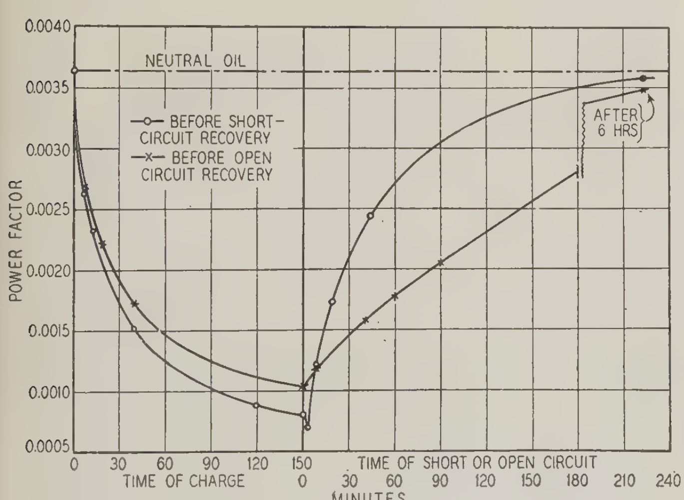

Fig. 3. Cleanup and recovery on open circuit and on short circuit

Oil B-6, at 1,500 volts direct current, and 60 degrees centigrade

regards value of stress, temperature, or other changes bearing on the diffusion or movement of the liquid between the condenser surfaces. It is believed that the unexplained behavior as between figures 4 and 5 may be due to this cause. Other examples are shown in figure 6, in which on recovery oil B-19 attains a phase difference value 9 per cent higher than that preceding the cleanup process, and in figure 7 in which oil B-8 suffered an increase of phase difference during the cleanup and a decrease during the recovery period. These variations from the more normal type of behavior apparently are due to

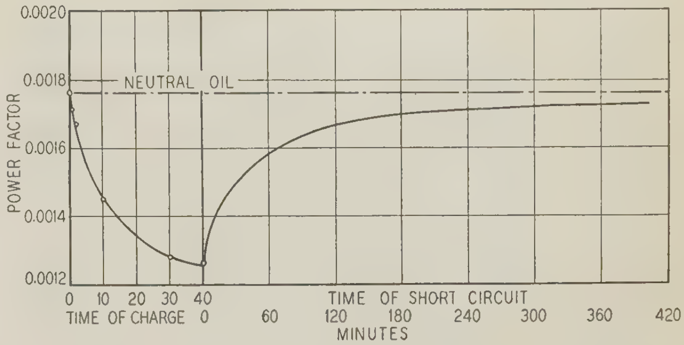

Fig. 4. Cleanup and recovery on short circuit

Oil B-8, at 500 volts direct current, and 45 degrees centigrade

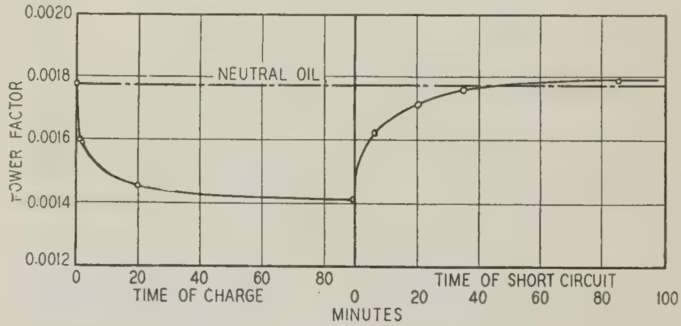

Fig. 5. Cleanup and recovery on short circuit

Oil B-8, at 1,500 volts direct current, and 45 degrees centigrade

clouds of space charge remaining from preceding tests and which, owing to the low mobilities of the ions involved, have remained intact during intermediate periods and so make their appearance only under the sustained voltage of subsequent tests. Several cases of this type were noted, but in each of them a variation in the normal cleanup period was followed by the opposite variation in the recovery period as indicated in figure 7.

In general the cleanup experiments are consistent with the view that the cleanup process is due either to the complete withdrawal of ions from the liquid, or, in order to account for the process of recovery, to the accumulation of ions as space charges near or at the surface of the electrodes, or perhaps to both. The experiments support this view principally in the influence shown of variations of temperature and electric stress. Increase of temperature lowers the viscosity and increases ionic mobility; higher stress obviously increases ionic velocities; both effects thus accelerate the cleanup process.

Conductivity Time

Figure 8 shows the time-current relations under continuous potential for oil B-8, the record beginning

a few milliseconds after the application of potential. These curves are typical for oils of these types. The initial horizontal portion represents a value of conductivity which accounts completely for the loss under alternating stress over a wide range of values.[4] It will be noted that this initial constant value is limited to a time interval of less than one second. Thereafter the current decreases, approaching ultimately a much lower constant value. Wide variations are found in the ratio of the initial to the final values. Generally speaking this ratio is greater the more highly refined or purified the oil. With moderate degree of oxidation or other impurity, the ratio may be very low, i. e., the initial and final values may be closely the same.[7]

The decreasing portion of these curves obviously gives the conditions obtaining during the cleanup process. Cleanup therefore is in effect a steady reduction of conductivity. This reduction may be due to the steady withdrawal of the excess of ions over their normal rate of production in accordance with gas theory, or as seems more important here, to the accumulation of space charges consisting of large molecular aggregates in the neighborhood of the electrodes. The relation between the progressively changing conductivity and the corresponding change of phase difference as a measure of the cleanup process is shown in figure 9. Here, for 2 of the oils, it is seen that the phase difference-time and the d-c current-time curves are closely identical in shape. Moreover, computations were made of the alternating loss as based upon the conductivities represented by the current-time curves. The values of loss so computed were of approximately the same values as the measured losses. The computed losses were, however, always somewhat lower than the measured values. This is attributed to the fact that these oils all show an ascending phase difference-voltage curve,

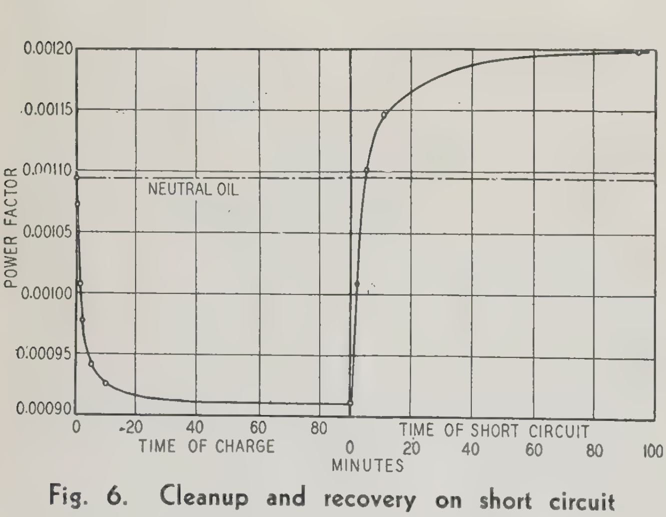

Fig. 6. Cleanup and recovery on short circuit

Oil B-19, at 1,500 volts direct current, and 45 degrees centigrade

indicating that under alternating stress new ions are created, probably by the process of secondary ionization. In such a case, the excess of measured over computed losses, referred to in connection with figure 9, would be explained. These results clearly indicate that d-c conductivity is the origin of the a-c losses (in the low frequency range), or in other words, that the cleanup process as measured by phase difference is due to a reduction of conductivity, and that the alternating loss is due to the motion of the same ions which are involved in d-c conduction.

Space Charge

It has been shown by Mie[9] and others that on application of continuous potential difference to insulating liquids, the potential gradient is not uniform but is steeper near the electrodes than at the center. The time rate of accumulation of these non-uniform gradients was studied by Whitehead and Marvin[6] who showed that it was generally contemporaneous with the slow decay of charging current and that the phenomenon was accompanied by a volumetric accumulation of space charges near the electrodes. These space charges obviously account for the higher potential gradients near the electrodes, and through their counter electromotive force of polarization for the slow decay of current under continuous potential, as shown in figures 8 and 9. The same authors also showed that current-time curves taken with the oscillograph for very short time intervals following a reversal of the applied

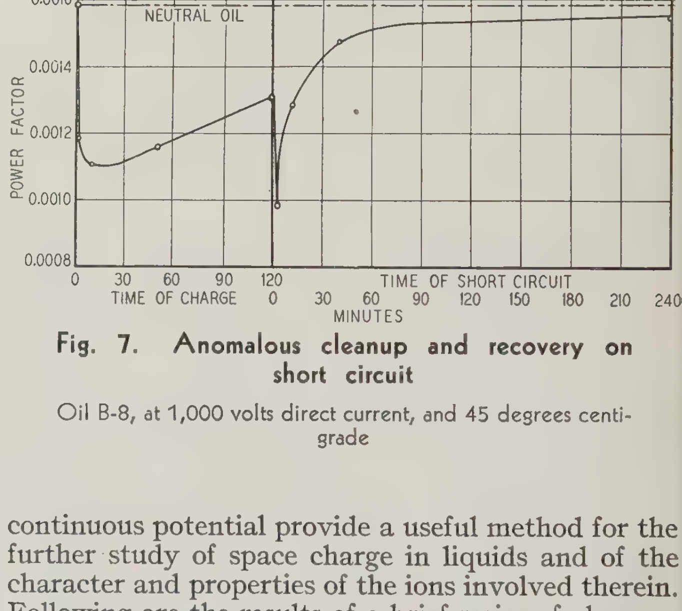

Fig. 7. Anomalous cleanup and recovery on short circuit

Oil B-8, at 1,000 volts direct current, and 45 degrees centigrade

continuous potential provide a useful method for the further study of space charge in liquids and of the character and properties of the ions involved therein. Following are the results of a brief series of observations of this character.

When continuous voltage is applied to an insulating liquid, the current-time curve is of the type indicated in figure 9 (the initial stages are of the type shown in figure 8). At the end of a sufficiently long time, in the above cases 40 or 50 minutes, the current reaches a constant value fixed by the relation between the applied potential difference, the counter electromotive force of polarization due to space charges, and the rate at which new ions are formed in the liquid. Now, if following a brief instant of short circuit for the passage of the geometric charge, the applied potential be reversed, the reverse current begins at a relatively low value, from 1 to 2 times the

value of the preceding steady current under opposite polarity, and thereafter rises sharply to a maximum from which the descent of current value may be more or less rapid according to the potential difference, but which ultimately reaches the same final constant value representative of the preceding long-time state under opposite polarity. An example of such a curve is shown in figure 10 taken on oil B-19. The initial steady low value may last for a second or more.

This type of behavior is readily accounted for by the effect of the reversal of polarity on the accumulated space charges. On reversal of polarity there is a much higher internal potential gradient, since the polarizing potential difference due to the space charges and that of the applied potential are now in the same direction. Consequently, the space charges

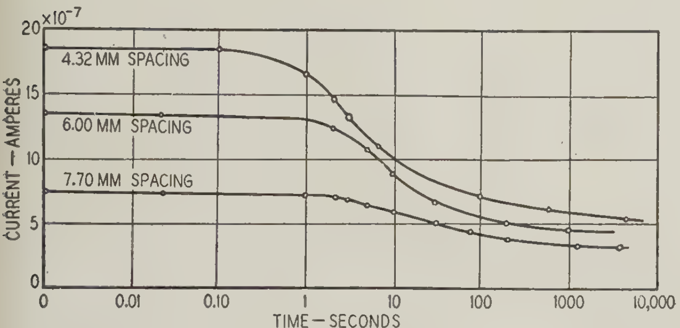

Fig. 8. Initial current-time relations on charge

Oil B-8, at 1,500 volts direct current, 60 degrees centigrade, and at millimeter spacings shown

begin to move, and with increasing velocity and increasing numbers in motion they unite to form the maximum as shown. As they pass to the opposite electrodes, a new accumulation of space charge takes place with counter potential difference due to polarization and the consequent slow approach to the steady state as in the preceding case of opposite polarity. In this picture, however, explanation of the initial constant value of current is not immediately obvious. Apparently it must be assumed that the ions constituting the space charge are large, heavy, and either that their mobilities are so low that they contribute little to the initial current, or that there is a time lag in reaching final velocities. The initial current on reversal therefore would be due as indicated by its initial value to the same ions constituting the final current at opposite polarity. This question is discussed in some detail below.

Figure 11 shows the general type of variation of the value of the current at the maximum with temperature. For 3 values of potential gradient it is seen that the maximum of current increases rapidly with temperature but considerably less rapidly with stress. Both types of behavior are readily accounted for by the increased ionic velocities due to reduced viscosity and higher potential gradient, respectively. The quantitative relationships indicated for the variation with potential gradient should be considered with some reserve as the variation in gradient was obtained by varying the distance between electrodes. This introduces the factor of the volumetric distribution of space charge as related to distance between plates, which has been found in other observations to have an important influence on both value and time variation of the current.

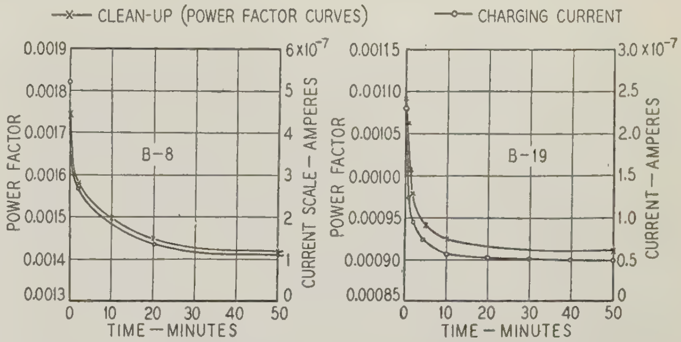

Fig. 9. Correlation of power factor-time and continuous current-time characteristics

Oils B-8 and B-19, at 1,500 volts direct current, and 45 degrees centigrade

The variation of the elapsed time from the application of reversed potential to the occurrence of the reversed current maximum, with applied stress and constant electrode separation, is shown for 3 temperatures in figure 12. Here, again, the normal influence of increasing stress and decreasing viscosity on the ionic velocities is evident. Toward lower stresses both the elapsed time to the maximum of current and the value of the maximum increase rapidly. This is evident in many oscillographic records. In some of these in the lower range of stress, it is difficult to detect the maximum. Under these circumstances it appears that the conditions obtaining on short circuit without reversing potential are approached. On short circuit, it is rarely possible to detect any reversed current. The space charges under their mutual attraction slowly diffuse toward each other and recombine. This behavior alone would constitute a reversed current. Such current, however, is neutralized by equal and opposite current in the external circuit caused by the liberation of the stored or bound charge on the condenser plates due to the space charge. In considering these observations on short-circuit conditions, it is to be remembered that the geometric charge corresponding to the capacitance of the condenser has been dissipated during the first instant of short circuit, its effect on the measuring equipment being eliminated by corresponding short circuit of the latter.

The relation of space charge movement to the initial period of the current-time curve is also indicated in figure 8, in which this curve is shown for 3 different values of potential gradient. It will be noted that there is an increase in the duration of the initial constant value of current as the potential gradient is decreased. If it is assumed that this initial constant value is in large measure due to the motion of accumulated ions in the body of the liquid in the original neutral condition, it is to be supposed that these would move to the electrodes more

rapidly at higher values of potential gradient and so establish the counter potential difference of polarization at an earlier instant than that corresponding to lower values of gradient. Other studies have been made, and are continuing, of the relations of the time intervals and values found in these reversed curves

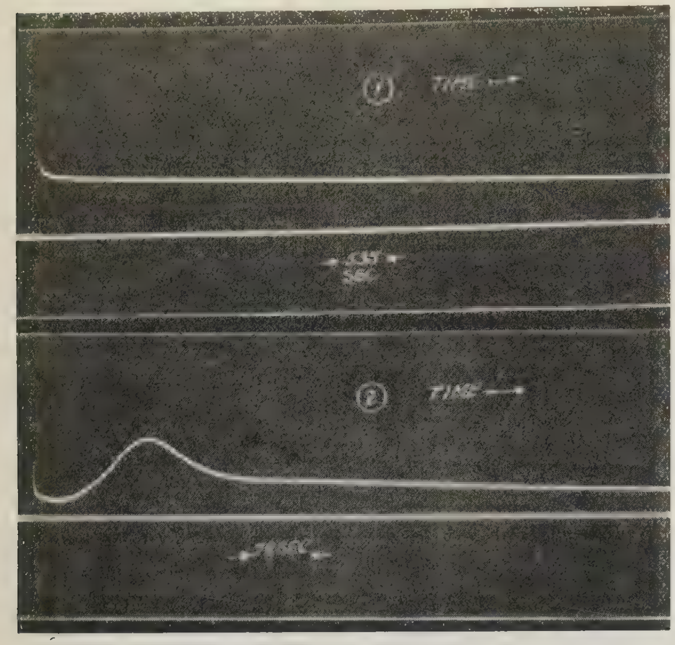

Fig. 10. Oscillograms of current-time relation for charge and subsequent voltage reversal

Oscillogram 1—Oil B-19, at 1,500 volts charge voltage, 60 degrees centigrade, 4.32 millimeter spacing

Oscillogram 2—Oil B-19, at 750 volts charge voltage, 750 volts reversal voltage, 72.5 degrees centigrade, 4.32 millimeter spacing

to the total value of space charge, to variations in potential gradient, and other aspects all in their bearing on the probable character, sizes, and mobilities of the ions involved.

Discussion

The phenomena underlying the electrical behavior of insulating liquids may therefore be pictured somewhat as follows:

In the neutral state even when highly purified, such liquids always show some electrical conductivity, albeit of exceedingly low values. This conductivity is due to ions arising either in traces of impurities, inherent dissociation, radioactive influence, or cosmic rays. Obviously, all these causes may be involved. The rates of recombination and diffusion of the ions so formed will at first be slower than that of their generation and the total number present will rise to an equilibrium condition where the number of recombinations is equal to the number of new ions formed per second. Some of the free ions so present attract to themselves clouds of neutral molecules thus constituting large and sluggish ions. Under normal electric gradients, an ion may carry with it as it moves a part of this surrounding cloud. As the gradient increases, however, it may be expected finally to shed the cloud completely. Further, at low gradients, positive and negative ions may be drawn together, but still remain separated owing to the intervening cloud, thus forming large polarized aggregates.[10]

When a potential difference is applied, if not too high, there will be motion of both the old heavy ions and the newly generated free ions toward the electrodes. The heavy ions will move much more slowly, and if they are sufficient in number, a practically steady initial value of current may result as shown in figure 8. The tendency to a decrease in current due to the arrival of some of the ions at the electrode would be off-set by an increase in the mobility of the heavy ions due to the shedding of the clouds of neutral molecules as their velocity rises.

As the ions arrive at the electrodes some of them are discharged but others of them are not discharged retaining enough of their neutral envelopes to prevent complete arrival at the electrode surface. Space charges will therefore accumulate near the

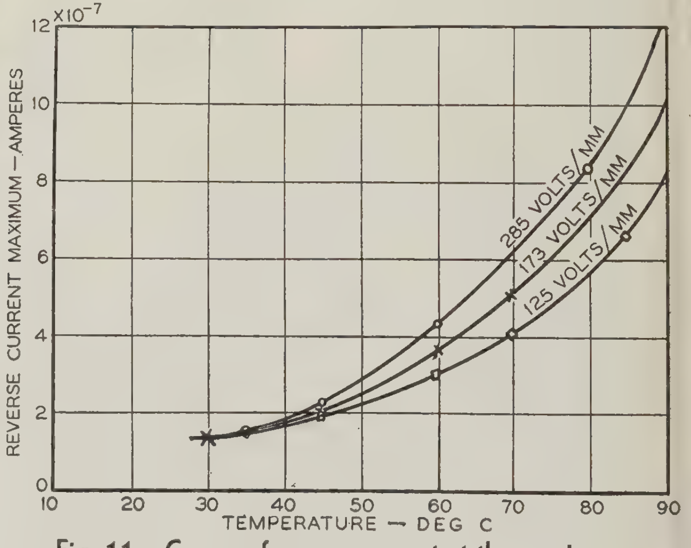

Fig. 11. Curves of reverse current at the maximum, versus temperature

Oil B-19

electrodes due partly to the steady withdrawal of freshly formed ions from the central regions, and their greater density near the electrodes (following a similar behavior in gases) and also due to the accumulated and stationary heavy ions with their surrounding clouds of neutral molecules. Both of these elements of the space charge are necessary for a complete explanation of the phenomena as observed. With the progressive accumulation of the space charges so formed, the potential gradient increases near the electrodes but falls off in the central region with resulting decrease of current so that the final steady current, if the gradient is sufficiently high to reach the saturation region, is due only to the number of free ions formed per second.

The long-time charging current is due principally to the steady supply of newly formed and more

mobile ions. The space charges reduce the internal potential gradient below that due to the applied field. On reversal of the applied field, therefore, the counter space charge potential gradient is now added to that of the applied field. As a consequence, the initial reverse current should be greater than the preceding final current of opposite direction. As stated above, this initial reverse current is invariably greater than the preceding final current, usually twice as great or somewhat less than twice as great. Moreover, the initial reverse current is of constant value over an appreciable interval, say up to one second. These facts strongly indicate that the initial reverse current is also due only to the newly generated mobile ions, the conductivity for this brief period being the same as the final conductivity of the preceding opposite period.

The reverse current maximum is due apparently to the space charge stored up in the large sluggish ions, for no such maximum is to be expected from the new more mobile ions. The initial reverse current represents the maximum current due to these latter. Consequently, the pronounced maxima of from 2 or more times the value of the initial charging current of the neutral liquid must be due to the additional supply of heavy ions stored in the space charge. Additional support of this view is found in the relation between the numerical values of the initial reverse current (A), the maximum reverse current (B), and the initial charging current of the neutral liquids (C). In surprising degree throughout many observations, the relation $B - A = C$ was found. Inasmuch as both A and C are attributable only to the newly formed mobile ions, it is clearly suggested

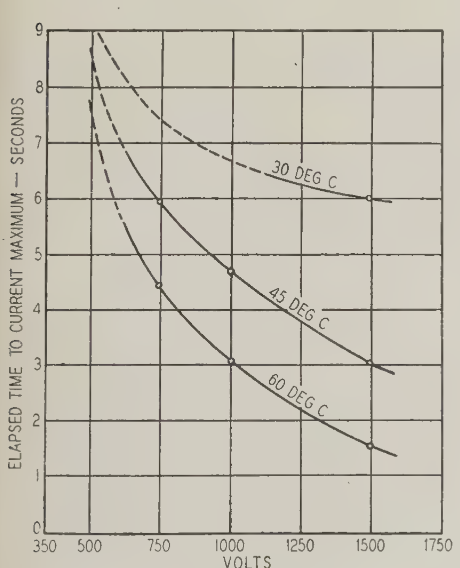

Fig. 12. Variation with voltage of elapsed time to maximum of the reverse current

Oil B-19, at 750 volts direct current, and at 6 millimeters spacing

that the excess of current over the initial reverse current must be due to an additional supply of ions, i. e., to the sluggish ions with their crowds of neutral molecules.

In the cleanup process, there is the accumulation of space charge due to both types of ion and the decrease of conductivity as described. During recovery on open circuit the space charges are more or less bound in position by the stored charges on the condenser plates. Diffusion and recombination are therefore retarded and recovery of initial conductivity is slow. On short circuit the geometric charges of the condenser combine through the external circuit, and the forces of diffusion and recombination have free play resulting in a much greater rate of recovery of initial conductivity.

Dielectric loss is due to the freshly formed more mobile ions. The central ions of the heavy aggregates are restricted in motion by their envelopes of neutral molecules and as a consequence, contribute little to the loss. Dielectric loss (at low frequencies) is therefore at all times related to the measured value of conductivity, as for example, in the initial value of the charging current of the neutral oil, and in the successively diminishing values of charging current during the cleanup process. During the recovery period the increase in loss is due to the increase in the number of new mobile ions.

Summary

In insulating liquids the conductivity-time relations, the reduction of conductivity and dielectric loss by the continuous application of continuous potential, and the occurrence of space charges at the electrodes are intimately related phenomena. In the purer liquids, the conductivity decreases with time after a brief initial period in which the conductivity is approximately constant. The decrease in conductivity is due to the accumulation of space charges at the electrodes, made up in part of freshly formed mobile ions and in part of heavy molecular aggregates with ions at their centers. The high maxima of current observed on reversal of the applied potential are due to the space charge in the heavy sluggish ions. These heavy ions thus have an important influence on the final measured value of conductivity under continuous potential, but contribute little if any to the dielectric loss under low frequency alternating potential. Dielectric loss is in most cases a pure conduction phenomenon as determined by the brief initial constant value of conductivity.

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Rehabilitation of the Connors Creek Plant

A decision as to when and how an electric power plant should be rehabilitated is largely a matter of judgment. In deciding to begin rehabilitation of the Connors Creek plant in 1933, the engineers of the Detroit Edison Company gave careful consideration to many factors including obsolescence of equipment, expected load growth, and general economic conditions. In deciding to rehabilitate the plant by replacing the boilers and generating units, they studied carefully such factors as the better heat rate obtainable with new equipment, the possibility of salvaging parts of the old plant, operating and maintenance costs, and reliability. This rehabilitation program is scheduled to be carried out in 4 major steps, the first of which will be completed during 1935. The process of reasoning followed in the development of this program and the principal results obtained and anticipated are outlined in this paper.

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ALTHOUGH a power company usually is thought to have a monopoly in the sale of electricity in its territory, its product is in constant competition with other forms of power and small plants available to its customers. It follows then that the operating company must furnish energy at the lowest possible cost consistent with satisfactory service, and to this end old plant and equipment should be replaced with modern and more efficient units when economically sound to do so.

The determination of when to rehabilitate a power plant presents a very complex problem the solution of which cannot be obtained by formulas. In the first place equipment does not become obsolete in any given span of time; instead, obsolescence is determined by improvements in the art in a given period. Again depreciation is a matter of quality of material and labor of which there is a considerable range. Factors such as the financial condition of a company, general economic conditions, and expected growth of load will have a very important bearing on when such projects should be started. Consideration of these factors makes it quite evident that no general statement can be made of the age at which a plant should be rehabilitated. Instead each project presents a separate and distinct problem having its own particular solution.

There is a lack of certainty in results of most rehabilitation projects even though there is a full knowledge of physical conditions and operating characteristics of old apparatus and of new equipment available. Usually the work can be done in several different ways, each of which may show some advantage depending upon the conditions assumed. As studies must be based upon predicted costs of fuel, labor, and materials, and upon an assumed growth of load, results obtained cannot be foreseen exactly. This is compensated in part by the fact that such programs usually proceed in steps which can be adjusted with changes in conditions.

Summed up, when and how to rehabilitate a power plant is largely a matter of judgment. The decision will be influenced to a great degree by past experience and belief in future trends, and in addition by engineering facts and conditions existing.

This paper describes the rebuilding program for the Connors Creek power plant of The Detroit Edison Company. Some phases of this project were immediately necessary to provide satisfactory operating conditions, while others were dependent upon load growth. The decision to proceed with the entire project was based upon the belief that load in Detroit soon would resume its former rapid growth, upon the fact that prices of material and money were favorable, and upon the recognition of the benefits to the community of such a construction project under existing economic conditions. To provide a background, a brief history of the plant is given with particular reference to past and probable future load conditions. Basic engineering decisions are stated and reasons given for them. Finally some of the outstanding features of the new plant are described and comparisons made of the old and the new. Descriptions are confined to statements of fact and opinion without the inclusion of a great deal of technical data. When the project is completed, the plant will be modern both in performance and appearance.

History

Construction on the original Connors Creek plant was started in 1914. When completed it housed 3 20,000 kw, 1 30,000 kw, and 2 45,000 kw generating units. These machines and the ties to the rest of the system permitted a load of 150,000 kw in the Connors Creek area.

Steam was used at a pressure of 220 pounds per square inch and a temperature of 600 degrees Fahrenheit. In its early days the plant heat rate was 21,000 Btu per kilowatt-hour and by 1929 this rate on the

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completed station had been reduced to 19,000 Btu per kilowatt-hour. Although Connors Creek was better than its contemporaries, with time it had fallen behind the company's more modern plants where the heat rate is approximately 14,100 Btu per kilowatt-hour.

The electrical system of The Detroit Edison Company is divided into load areas interconnected by ties for mutual help in emergencies. Connors Creek plant serves a load area consisting of the east side of Detroit in which is concentrated a great deal of the city's automobile industry. It is history that load increases at a greater rate in this area than in the others and that after a depression the "comeback" is most rapid. All information indicates that future load growth in the area will follow past trends. In 1929 the area load nearly equaled the firm rating of facilities available to serve it.

The original switching station in the generating plant building had become inadequate, as a result of system growth. Interrupting capacities of circuit breakers were less than the possible short circuits, proper segregation of equipment consistent with changed conditions was not provided, and the cable vault was crowded. In general, the standards of this important supply station were considerably below those of the more modern ones of the company. Because of these facts, studies were begun in 1928 on programs that would provide adequate switching facilities, additional capacity, and the rehabilitation of the comparatively old and inefficient equipment.

Basic Engineering Decisions

In the beginning, studies of the switching problem were pressed, as it was necessary to provide improved switching facilities regardless of what was done to the generating plant. Furthermore, it was desirable to get this work out of the way of the then future generating project.

Switching Station. As reported and discussed in detail in a previous A.I.E.E. paper[1] investigations soon indicated that it was not feasible to "revamp" the then existing switching equipment housed in a bay of the power house building, and that the proper procedure was to build a new detached switch house, with a bus and equipment arrangement that would be flexible enough to accommodate any probable future generating plant development. The station operates at 24 kv, supplying the cable system of that voltage. Generators are connected to the busses through autotransformers, each generator and its autotransformer operating as a unit.

The scheme of connections chosen was that of the single-bus single-breaker equalizer or synchronizing bus type, a choice consistent with The Detroit Edison Company's fundamental plan for system development which permits indefinite growth without making existing switching equipment inadequate. This plan provides that the transformers of the substations in a load area be fed radially from the supply station, that the feeds for a particular substation be distributed among the bus sections of the supply station, and that the tie lines to adjacent load areas be brought to the equalizer bus of the supply station. Thus, by changing the reactance of the equalizer reactors, generator sizes can be changed without changing the switching equipment. This co-ordination of system and switching station design makes the use of single busses and switches entirely logical.

Work on the switching station was begun in 1930, and it was put in service in 1932.

Generating Plant. In conducting the generating plant studies, the principle was laid down that simplicity and reliability were to be emphasized and that no attempt for an efficiency record was to be made at the expense of these factors. Also, experience gained in other plants of the company was to be utilized and practices there developed were to be followed, if they stood up under close scrutiny. At the start it was recognized that certain predilections existed in the minds of the operating staff, and it was agreed that these should be tested and followed out only when found to be sound.

It was decided that for either a new or a rehabilitated plant, the steam pressure would be 600 pounds per square inch and the temperature 850 degrees Fahrenheit, and that a simple regenerative cycle would be used. Although these steam conditions are higher than those in the company's other plants, they were not adopted without some previous experience. Since 1931 an experimental 10,000 kw machine using steam at 365 pounds and 1,000 degrees has been in operation at Delray station, and experience gained from this machine influenced to a great degree the selection of steam conditions for Connors Creek. Reheat cycles were studied but were ruled out because of the belief that the gain they provided did not warrant the added complexities, and because the company did not have a background of operating experience with them.

Although pulverized fuel is used successfully at the company's Trenton Channel plant it was decided to continue the use of stokers at Connors Creek. This decision was based primarily upon the ability to reuse the bunkers and coal handling facilities of the old plant and upon the difficulty in disposing of the ash of pulverized fuel. At Trenton Channel the ash has been used as fill in the large area around the plant, but in the future its disposal will become a problem. At Connors Creek it would have to be hauled away at the expense of the company, whereas cinders can be disposed of at no cost. Also, it was believed that the characteristic stack discharge from the stoker plant would be more satisfactory to the public as it had become used to this from the old plant.

Methods Considered

The desired results could be obtained by one of 2 general methods. By the first, the old plant would be retained as long as possible and added capacity installed in a completely new plant on the site as needed. Ultimately, the old plant would be replaced. The second general method was to rehabilitate the old plant, at the same time providing

1. For all numbered references see list at end of paper.

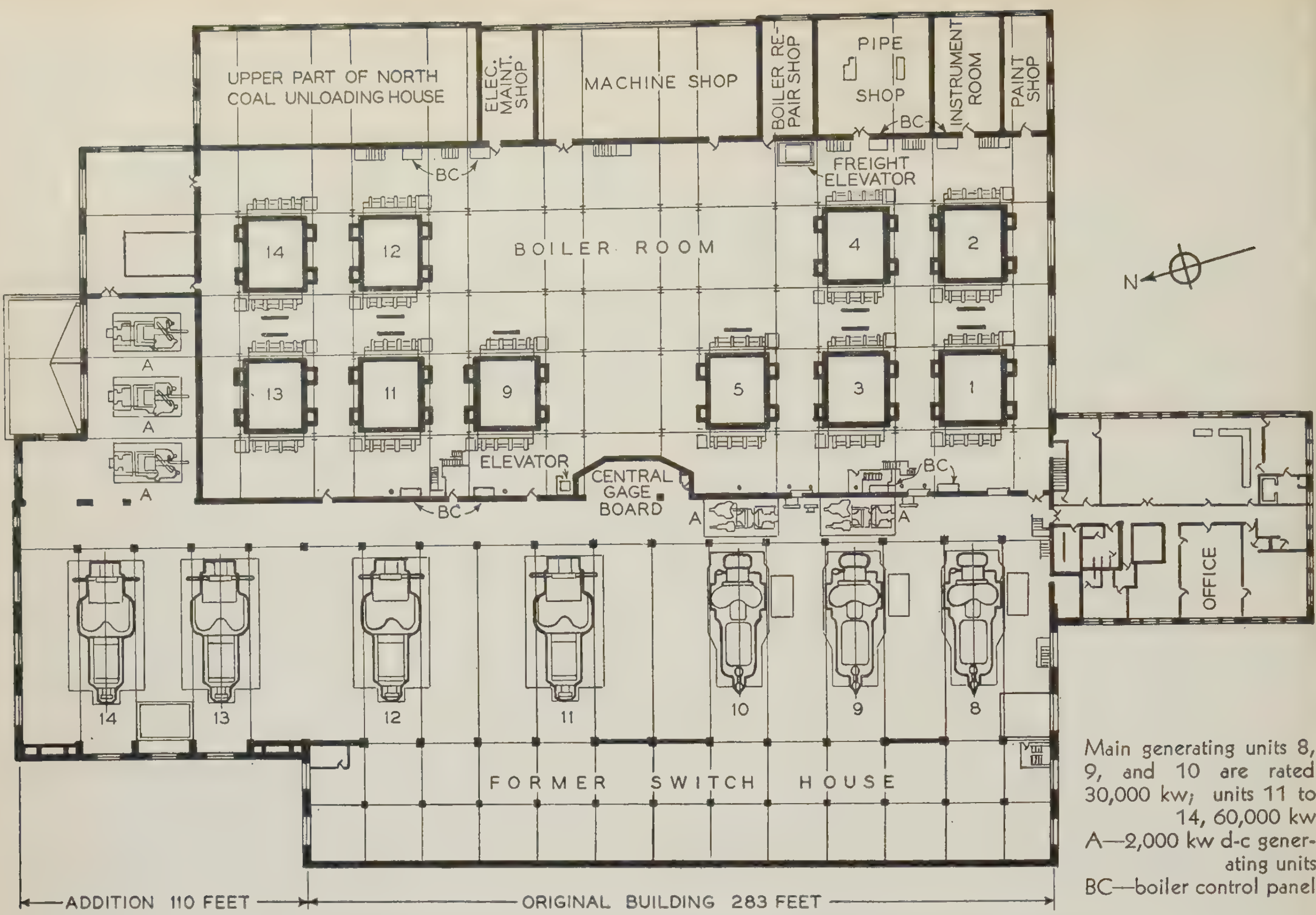

Fig. 1. Operating floor plan of Connors Creek station after rehabilitation is complete

for increased capacity. This could be accomplished by replacing the old generating units with new ones or by superimposing high pressure machines on the old units.

It was recognized early that the adaptability of the old plant for increased capacity and the amount of it salvageable with rehabilitation would be important factors in the final choice of plan. Studies showed that in the turbine room space was sufficient and foundations adequate to replace the old 20,000 and 45,000 kw units, respectively, with modern 30,000 and 60,000 kw machines. Furthermore, with minor changes the condensers of the old units, with their auxiliaries, were entirely adequate for the new larger units. By a relatively small building addition space could be provided for 2 additional 60,000 kw generating units. In the boiler room it was found that column spacing and foundations were such that the old boilers rated nominally at 10,000 kw could be replaced by new high pressure units having more than 3 times this capacity. These new boilers needed greater head room which would require raising the boiler room roof 32 feet. With this replacement program, the plant generating capacity could be increased to 330,000 kw or nearly double that of the old plant, and the plant structure and foundations, stacks, canals, coal handling and condensing equipment, and numerous parts of apparatus could be salvaged at a comparatively small cost. Because of the general rearrangement necessary, little of the piping even of the service type could be retained.

In considering the desirability of providing added capacity in a new separate plant these facts were weighed: First, because of its age the old plant would have to be replaced in a relatively few years, and during this time it would be used as little as possible because of its high heat rate. Operating and maintenance costs would be high, and reliability would be not of high degree. In general, this plan was not attractive from an operating standpoint.

Of the 2 methods of rehabilitating the old plant, that by which the old generating units were replaced by new ones gave the better heat rate and provided greater ease in operation. With the other method, by which high pressure units would be superimposed on the old machines, high maintenance and lower reliability, inherent in old equipment, would be retained. With either plan the boilers would have to be replaced completely.

Economic studies covering several years of estimated future operation were made of the several plans. As a result of this work, and by the application of what seemed to be common sense values to such intangibles as reliability and operating features, it was decided that in the long run the best procedure would be to rebuild the old plant and to replace the old generating equipment with new.

With this major decision made detailed plans were developed which provided in plan a layout as shown

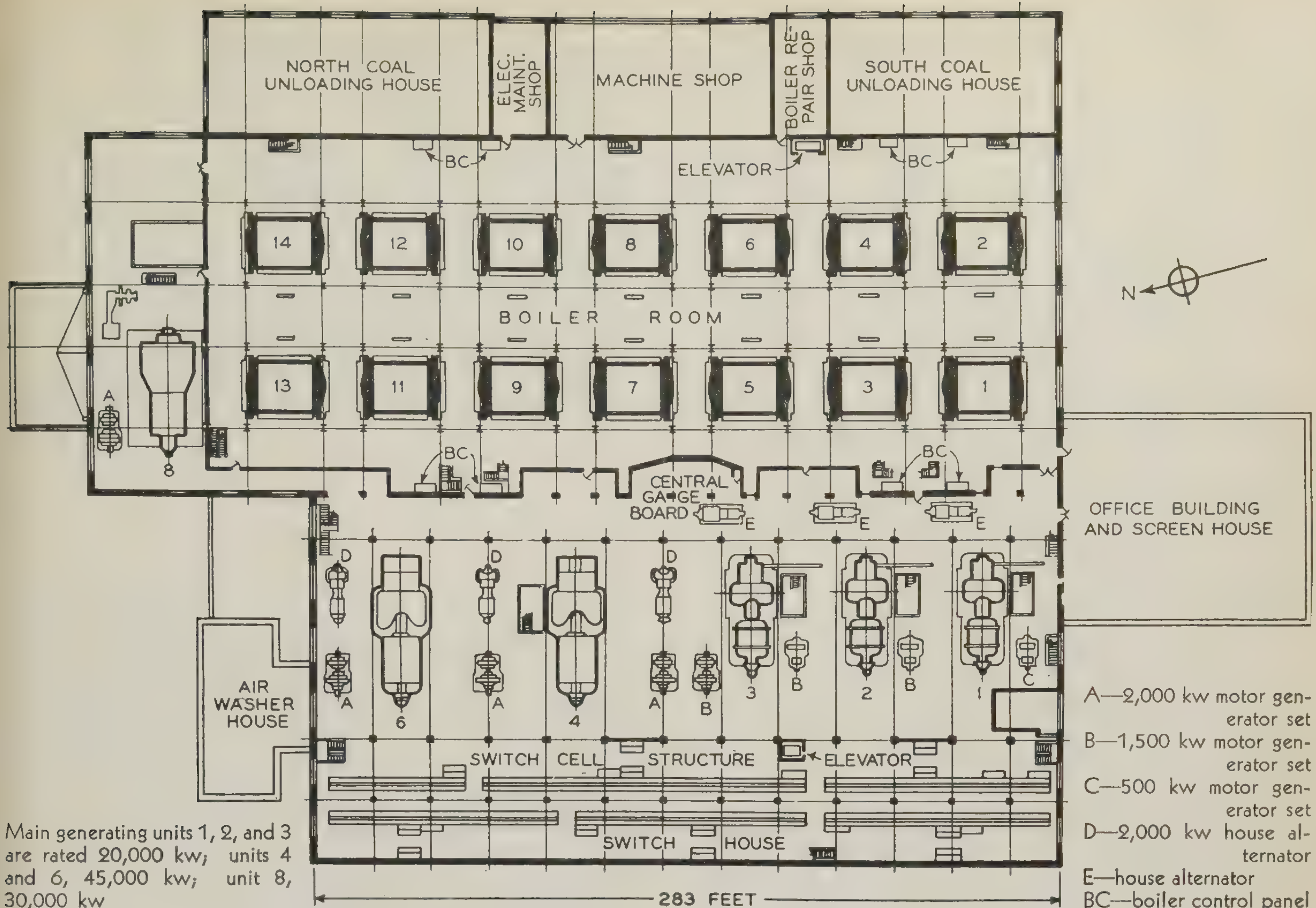

Fig. 2. Operating floor plan of Connors Creek station before rehabilitation was begun

in figure 1. Figure 2 is a similar plan of the old plant presented for comparison. In the new layout units 8, 9, and 10 occupy the positions of units 1, 2, and 3 of the old plant; units 11 and 12 replace units 4 and 6 of the old plant; and units 13 and 14 are located in an extension of the turbine room. Space occupied by unit 8 of the old plant will be used for house service machines in the new layout.

Schedule of Rehabilitation

With the rehabilitation plan developed, a time schedule for the work was established. This was extremely important in order to provide for the growth of industrial load expected in the area. As each replacement step temporarily reduces the plant capacity, and as each of these steps requires nearly a year for completion, the schedule and load growth curve had to be co-ordinated carefully. Obviously, it was highly desirable to start the work during this period of reduced load.

Load growth in the area in preceding years was studied, and from these data and other furnished by the statistical and sales departments of the company the load curve was predicted for 10 years hence. At any time the area firm capacity rating should be somewhat higher than the load in the area. This rating is equal to the sum of the ratings of the machines in the plant less the sum of the ratings of its 2 largest machines, plus the help that can be obtained through the system ties. This assumes that one machine is out of service for maintenance and that a second is lost through accident. It should be noted that it is not assumed that 2 machines can be out of service simultaneously in all power plants. Instead, the system firm rating is based upon 2 of its machines being out of service, and these *may* be in one plant or area.

The economics of all the sequences of replacement were studied. As a result of this work it was determined that the first step would be the removal of old 30,000 kw unit 8 and 20,000 kw unit 1, the latter to be replaced by a new 30,000 kw machine. This was to be followed by the replacement, in sequence, of the remaining 2 20,000 kw machines by 30,000 kw units. This work constituted the first phase of the program. As load requirements dictated, a new 60,000 kw machine would be installed in the turbine room extension, the two old 45,000 kw machines would be replaced in sequence by 60,000 kw units, and finally a second new 60,000 kw machine would be installed in the turbine room extension. Figure 3 shows how this sequence is matched with the load growth curve and indicates that nominal maintenance should be scheduled so that machines are not out of service for this reason during certain periods. This plan will be adjusted in accordance with actual load development. The first phase does not add any capacity but does replace machines nearly 20 years old with more efficient units. As an isolated case

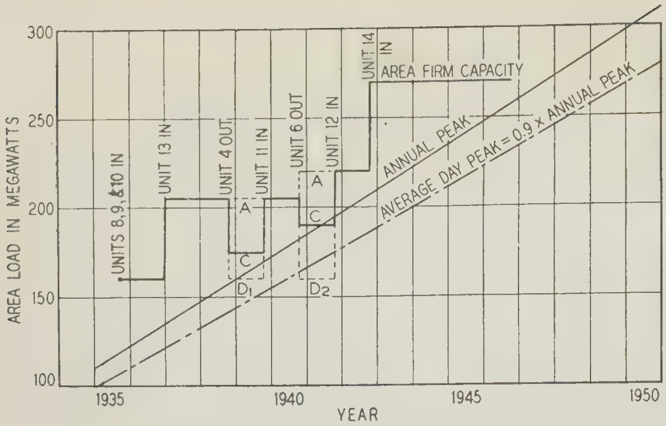

Fig. 3. Curves showing how the steps of the rehabilitation program are correlated with expected load growth

A—Firm capacity with one 60,000 kw generator out of service

C—Firm capacity with one 60,000 and one 30,000 kw generator out of service

D_1—Firm capacity with one 60,000 and one 45,000 kw generator out of service

D_2—Firm capacity with 2 60,000 kw generators out of service

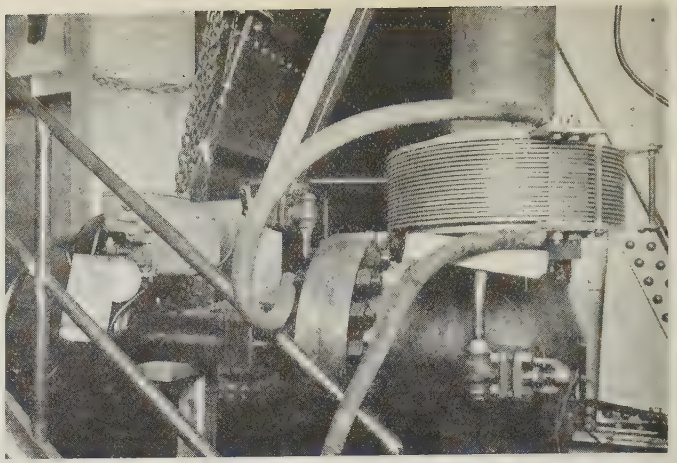

Fig. 4. Stress-relieving coil on welded joint in 10 inch main superheated steam line

this gain in efficiency will not completely warrant the added investment required. However, considering the project as a whole this sacrifice is necessary in order to meet the time schedule.

With the sequence program settled, work was started in 1933 on the replacement of old unit 1. The new machine, now called unit 8, was placed in service in 1934. Old unit 2 is now in the process of being replaced by new unit 9.* The first phase of the program will be completed during this year by the replacement of unit 3 by new unit 10. The work on these units was started somewhat earlier than was absolutely necessary, but this was justified by the fact that usually some operating time is necessary to work out minor difficulties in such new equipment, and because existing economic conditions permitted some modifications of the usual methods of justifying construction expenditures. For instance, it was recognized that this work would be of distinct benefit to the community and that it should be started immediately if it were to be helpful in relieving unemployment. This is an illustration of one of the many factors that affect rehabilitation programs.

Preparations are now under way for the second phase of the program. The extension to the turbine room is built and the first of the new 60,000 kw units has been ordered for delivery in the middle of 1936.

Features of Generating Plant

One feature of the new plant will be the amount of equipment salvaged from the old. This resulted from close scrutiny of the old equipment and through co-operation of the manufacturers. Also, as a result of much study, several processes, new at least to The Detroit Edison Company, have been worked out which it is believed will make the plant outstanding.

Generating Units. For 2 of the new 30,000 kw units the generators have been obtained from machines now out of service. One was from the 30,000 kw unit of the old Connors Creek plant and the second was obtained from a similar machine installed in old Delray power house 2. The generators are in good shape and are entirely suitable. Included in the construction of the turbines are the exhaust casings of the 20,000 kw units which they replace and the pillow blocks of the old 30,000 kw turbines. The appearance and performance of these units will equal that of new machines. The third 30,000 kw unit will be entirely new except for the turbine exhaust hood.

Condensing Equipment. A series of studies and tests made on the condensers of the 20,000 kw machines showed that with a different arrangement of tubes they would be adequate for the new 30,000 kw units. Actually, this arrangement uses fewer tubes than were used for the smaller machine. Further investigation showed that by the same process the condensers from the old 30,000 kw units from which the generators were obtained could be used for the new 60,000 kw units to be installed in the turbine room extension. Similarly, it was found that the condensers of the 45,000 kw units would be adequate for the 60,000 kw machines replacing them. As a result of these investigations no new condensers and practically no new condenser auxiliary equipment will be purchased for the new plant.

Welded Piping. Experience gained from the experimental 1,000 degree machine at Delray station brought out the weakness of bolted joints subjected to wide temperature changes; hence for Connors Creek it was decided to weld all of the main steam piping and most of the other high pressure piping including pipe-to-valve connections. This decision was based upon the development over a period of years, by the company's construction staff, of technique and men to produce high-class welds.

Each weld is checked with a device called an "archronograph" by means of which defective work may be detected. In addition the welds are stress-relieved in place by means of an induction coil developed for the purpose. This coil is made up of heavy flat conductors hinged on one side to permit slipping over the pipe. Current at 60 cycles and low

*Replacement completed since paper was written.

voltage passed through the coil induces a circulating current in the weld which raises its temperature to 1,100 degrees Fahrenheit in a relatively short time. The coil is separated from the pipe by an insulating sleeve. Figure 4 shows the stress-relieving coil in place.

Models. A modern steam plant is a very complicated assembly of equipment, and it is difficult to visualize from drawings exactly what the final physical appearance of the product will be. In designing the Connors Creek plant this difficulty was overcome by the construction of exact scale models in wax and wood. Such models are particularly helpful in designing clean cut piping layouts as they eliminate to a great degree the necessity of making expensive changes as the work progresses. Figure 5 shows a model of units 8 and 9.

Boilers. The new boilers each have a nominal rating of 33,000 kw and occupy the same floor space as the old boilers rated nominally at 10,000 kw. This increase in rating has been obtained by the use of water walls (which permit higher combustion chamber temperatures), by the installation of economizers and air preheaters, by a slight increase in grate area, and by the use of a type of forced draft control that permits a high rate of coal burning.

The forced draft control used is such as to distribute the air uniformly through the fuel bed. The space below the grate is divided into 72 air chambers all supplied from a plenum compartment. Each chamber is equipped with a damper and a Venturi throat which measures the air flow and acts through a control system on the damper to hold to a predetermined value the air supplied through each chamber. By adjustment of the control, the amount of air supplied can be regulated to suit the fire conditions. With this system a uniform fire is obtained with the possibilities of burning holes in the fuel bed practically removed. A continuous check of the air distribution is indicated by a bank of meters in front of the boiler.

Superheaters. In other plants of the company the temperature of the steam varies considerably with the boiler load, that is, the superheat is not constant. As considerable extra money is being spent at the Connors Creek plant for high temperature equipment and piping, it is highly desirable that the superheat be maintained constant in order to realize the maximum return on the investment.

The superheaters as designed for the new boilers will maintain essentially a constant steam temperature over the ordinary operating range. This is accomplished through control of the path of the boiler gases. On leaving the combustion chamber the gases divide into 2 paths, one on each side of the boiler, and meet before entering the economizer. In each path is a radiant superheater directly over the fire, and back of one of these is a convection superheater. A damper in each of these paths varies the relative flow of gas in such a manner as to increase or decrease at will the convection effect of the combination, thus affording control of the resulting superheat.

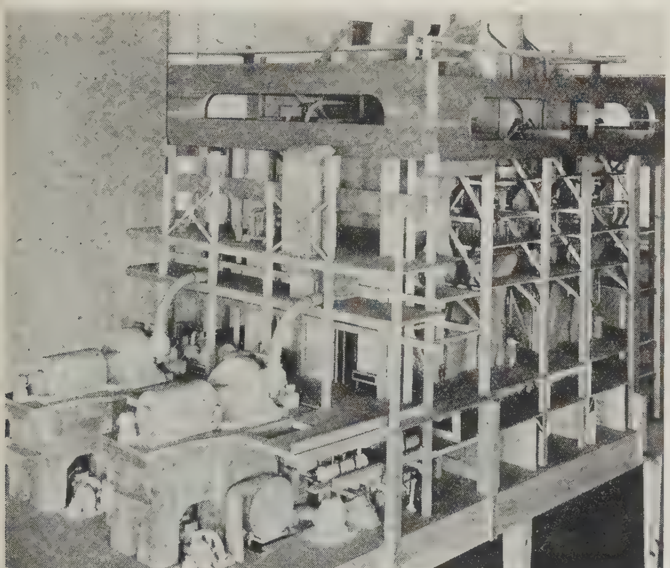

Fig. 5 (above). Model of new generating units 8 and 9 with boilers and other associated equipment

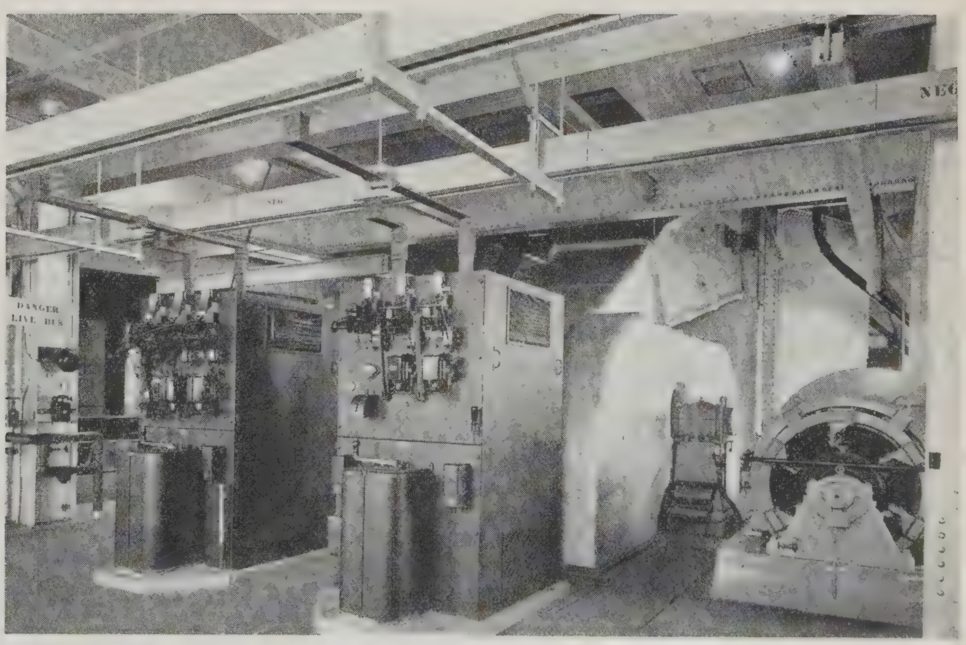

Fig. 6. View on fan room floor of boiler room showing forced draft fan control. Note d-c auxiliary bus construction overhead

Auxiliary Power. In accordance with past practice of The Detroit Edison Company, essential auxiliaries are supplied from a 240-volt d-c bus fed entirely independently of the main electrical system. One exception is made in that the boiler feed pumps are driven by slip ring induction motors supplied from the a-c house service. These, however, have stand-by steam driven pumps. The d-c system was adopted partly because of the motor drives salvaged from the old plant, but mainly because the company's experience indicates that the small increase in cost of the d-c system is warranted by the better and simpler speed control obtained.

The d-c bus used is single and not sectionalized, but is so constructed that it is practically proof against failure. The positive and negative sides each consist of 2 aluminum channels as shown in figure 6 and are spaced as far apart as possible, never less than 5 feet. The exposed surface of each channel is covered with a protective shell of formed horn fiber which does not obstruct movement of air for ventilation between the 2 channels. Because of the spacing and covering, short circuits between positive and negative busses are practically impossible. As the system is not grounded, ground faults are of no consequence. All taps taken from the busses are made through copper link fuses installed in small housings attached directly to the bus. Thus, although the leads may be brought together at the equipment, these fuses protect against a short circuit of the bus.

Costs and Comparisons

Costs of the project are summarized in tables I and II. Table I shows the book value and capacity for the old plant and for the various stages of rehabilitation. This table also gives the heat rate of the old plant and that estimated when the project is completed. Table II shows the make-up of the increase in book value for the completely rebuilt plant.

The following comparisons of design and performance of equipment in the old and new plants show the progress that has been made since the original plant was built.

Turbines. Engine efficiency of the new 30,000 kw units is 10 per cent higher than that of the old 20,000 kw machines. This increase is attributable partly to better design and partly to the higher steam pressure and temperature. The turbine heat rate of the 20,000 kw units at best point was 14,200 Btu per kilowatt-hour; that for the 30,000 kw units is 9,850 Btu. The future 60,000 kw units will show a similar advantage.

Besides being more efficient, the new turbines will be better operating machines. Turning engines are installed, and the design utilizes all knowledge of minimizing the effect of expansion in the turbine metals caused by temperature variations. The result will be machines that can be put into operation quicker and with less chance of trouble.

Condensers. The condensers as used with the old 20,000 kw units had 1.63 square feet of surface per kilowatt. As redesigned for use with the new 30,000 kw units the total surface, including the extraction heaters, is 1.07 square feet per kilowatt and for the condenser alone it is 0.90 square foot.

Boilers. Although the rating of the new boilers is slightly more than 3 times that of the old, the heat absorption is only twice as great because of the better water rates of the new turbines and because the feed water temperature is increased by the use of extraction heaters. The old boilers had 26,000 square feet of boiler and superheater surface. The new units have 48,000 square feet of boiler, water wall, economizer, and superheater surface. In addition, the new boilers each have 30,000 square feet of air preheater surface. Through the use of boiler water walls and metered air control the new boilers will burn 60 pounds of coal per hour per square foot of grate surface at nominal full load. In the old boilers the corresponding rate was 40 pounds. The temperature of the stack gases from the new boilers will be 325 degrees Fahrenheit; that from the old boilers was 650 degrees.

Although it is recognized that data obtained from

Table I—Values, Capacities, and Heat Rates of Connors Creek Plant During Various Stages of Rehabilitation

		Net Cumulative Book Values Including Overhead	Capacity, Kw	Average Btu per Kwhr
Old plant		$16,482,445	180,000	19,000
First phase of rehabilitation	3 20,000 and 1 30,000 kw units of old plant replaced by 3 new 30,000 kw units; 4 old boilers replaced by 4 high pressure units; Roof at boiler room raised. Extension made to turbine room	20,114,200	180,000	
Second phase of rehabilitation	1 new 60,000 kw unit added in turbine room extension; 2 old boilers replaced by 2 new high pressure units	23,312,200	240,000	
Third phase of rehabilitation	2 old 45,000 kw generators replaced by 2 new 60,000 kw units; 4 old boilers replaced by 4 new high pressure units	27,409,200	270,000	
Fourth and final phase of rehabilitation	Second new 60,000 kw generator installed in turbine room extension; Remainder of old boilers removed and 2 new high pressure boilers added	30,367,200	330,000	Less than 13,000

Table II—Summary of Construction Costs and Retirements for Complete Rehabilitation Project

Old plant book value			$16,482,445
Total new cash		$20,367,610	
Value of old equipment from other locations re-used		459,000	
Total rebuilding account		$20,826,610	
Credit to property	$6,005,950		
Cost of removals	935,905		
Total charge to retirement reserve		6,941,855	
Net addition to book value			13,884,755
Total book value of completed plant			$30,367,200

Book value of old plant includes $2,576,663 for switch house.
Book value of completely rebuilt plant includes $3,028,663 for switch house.

the first section of a new plant may not be entirely reliable, figures obtained during the short time that the first new machine has been in operation indicate that the average heat rate of the new plant will be less than 13,000 Btu per net kilowatt-hour delivered to the bus; for the old plant the average was about 19,000 Btu. In addition, the new plant will show a decided labor saving, being consistent in this respect with the Trenton Channel plant.

Not a Made-Over Job

In the program developed it is believed that fuel efficiency, reliability, and operation have been properly evaluated and balanced. The steam cycle and conditions chosen will provide an excellent heat rate and the arrangement of equipment made will produce low operating costs. Due recognition was given to the possible advantages of other cycles and methods, but these were abandoned after careful consideration of all the factors involved.

In appearance the plant will be comparable with a new one and will not have the characteristics of a made-over job. Equipment will not be crowded, and the piping layout will be particularly clean cut. Suffice to say, this program represents the company's best judgment of procedure under the conditions prevailing.

Reference

1. Switching at the Connors Creek Plant, A. P. Fugill. Elec. Engg. (A.I.E.E. Trans.), v. 53, Jan. 1934, p. 162–8.

Protective Signaling

Protection of life and property may be secured by electrical signaling systems which have been developed to give protection against damage to property by fire, burglary, and other causes, and to supervise the activities of night watchmen and the operation of different types of mechanical equipment, and to perform other services. This paper consists of a general outline of the types of service available and the electrical systems for accomplishing them.

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THE function of the protective signaling systems described herein is to detect hazards to property and to life involved in fire, burglary, robbery, and related risks, and to summon automatically the necessary aid for overcoming them. Speed in detection and transmission of the alarm is often a vital factor in combatting successfully a fire or robbery. A few minutes, or even seconds, may mean the difference between little or no loss, and disaster.

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Insurance considerations have been such powerful factors in determining the pattern of all protective measures that frequent references to insurance rulings are made herein. Insurance premium savings account for many protective signaling installations but even more are made for the preservation of intangibles not covered by insurance.

The functional technique of such systems is similar to that employed in the code signaling and communication fields. The infrequency with which these emergency systems operate, and the danger of catastrophe attendant upon their failure, demand a reliability far higher than that of most commercial signaling systems. Self-supervision and organized maintenance are essential. Malicious tampering with the protective systems has to be checkmated. False alarms must be held to a minimum.

Protective signaling is accomplished through the following main services:

1. Sprinkler supervisory and water flow alarm service.
2. Automatic and manual fire alarm service.
3. Night watchman supervisory service.
4. Miscellaneous supervisory services.
5. Burglary and holdup alarm service.

Protective signaling systems for fire protection are classified by the National Board of Fire Underwriters as:

1. *Central Station Systems.* These systems transmit coded signals to a central station for dispatching the fire department, salvage corps, police department, central station guards or "runners," or other agencies as prescribed by the insurance regulations. These systems are owned and maintained by the central station organization but supervised by the Underwriters through routine reports, periodic inspections, and surprise tests. Figure 1 shows a typical central station.

2. *Proprietary Systems.* These are similar to central station systems but have signals transmitted to a station located on the protected premises and are manned by a prescribed quota of full time attendants. Figure 2 shows one type of proprietary control equipment.

3. *Local Alarm Systems.* These consist of devices for sounding audible signals within the premises for the notification of occupants,

mainly as a protection against loss of life. They are generally considered of relatively small importance in the protection of property (industrial and mercantile) since they are ineffective during the unoccupied periods.

4. *Auxiliary Systems.* These systems are, in effect, local systems connected to municipal fire alarm telegraph lines for direct transmission of alarms to fire headquarters. The questionable propriety of directly associating municipal circuits with extensive private local wiring, with divided responsibility for maintenance and the fact that municipalities are not regularly organized to care for supervisory services, limits greatly the field for auxiliary systems.

Sprinkler Supervisory and Water Flow Alarm

The value of automatic sprinklers in fire control depends upon their being in perfect operating condition at all times. For this reason, protective signaling is effectively combined with sprinkler systems to insure their reliability.

Water flow alarms are of great importance because in reality they are fire alarms, and, because serious water damage may be incurred should the flow continue after the extinguishment of an incipient fire or through an undetected leak in the system. The signals are initiated by electrical switches actuated by the clapper of an alarm check valve when lifted by a flow of water in the system; by a differential pressure operated device actuated by a sudden decrease in the system pressure following the opening of a sprinkler head; or, by a movable vane located directly in the flow stream of sprinkler piping. Figure 3 is a diagram showing the principle of a differential pressure type water flow detector. The vane type is shown in Figure 4. To avoid freezing, sprinkler systems installed in unheated buildings usually have the piping filled with air instead of water. The opening of a sprinkler head permits the air to escape which opens a "dry valve" admitting water to the system. The admission of water pressure to an intermediate chamber in the dry valve actuates a switch which initiates the water flow alarm.

To minimize false alarms from water hammers and pressure surges the alarm valve and vane type of flow detectors usually have retarding elements of the mechanical clock work, electrostatic condenser, or thermoelectric type associated with them. The differential pressure type overcomes such conditions hydraulically.

The most efficient sprinkler system obtainable would be valueless if on the occasion of a fire no water were available, through lack of normal supply pressure, or inadvertent closing of a water supply valve. Supervisory service provides a constant check on the condition of all essential elements of the sprinkler system by means of actuating devices, attached to these elements, which initiate signals in case of any derangement.

Automatic Fire Alarms

Automatic fire detection is accomplished by elements classified as "continuous," that is, those which are heat sensitive throughout their entire length, or "spot type" thermostats which are localized heat sensitive units. A further distinction is made between "rate of rise" systems and fixed temperature systems.

The pneumatic type of continuous fire detecting system shown in figure 5, which operates on the "rate of rise" principle, consists of a continuous small copper tubing attached to the ceiling of the protected area, the 2 ends terminating in chambers closed by thin diaphragms. This tubing normally contains air at atmospheric pressure and room temperature. In case of fire, the sudden rise in temperature expands this air, pressing the diaphragms against contacts which initiate the signal. To prevent false signals resulting from a rise in temperature produced by a change in weather, vents are provided in each diaphragm chamber which compensate for such slow changes. Having a diaphragm on each end insures operation even though the tubing should become open at some intermediate point. The internal fric-

Fig. 1. A typical central office

Direct wire burglar alarm circuits are terminated on the drops in the switchboard in the background. Coded signals are recorded, timed, and checked on the tables in the foreground

tion of 20 feet or more of tubing builds up sufficient pressure to operate with an open end.

Systems which are actuated by the rate of temperature rise can be made to respond to a fire more quickly than a system actuated by a fixed high temperature. The speed is further increased in the pneumatic continuous type because of the cumulative effect of all tubing exposed to the heat.

Electrical types of "continuous" fire detecting systems operating on the fixed temperature principle are available. One type consists of insulated conductors of fusible material which is melted by a fire, opening the circuit and initiating the alarm. In another form 2 separate circuits are contained within a single sheath. A fire melts a fusible element which initiates an alarm by making a connection between the 2 circuits.

"Spot type" fixed temperature thermostats are available which open or close a circuit when the heat

Fig. 2. A proprietary system control desk of the annunciator-recorder type

The annunciator in the center of the superstructure provides a continuous indication of the condition of the sprinkler system. Night watch, fire alarm, water flow, and sprinkler supervisory signals are recorded in printed words and numbers by the printing recorder at the left, and in punched code by the automatic punch register set in the desk top

of a fire melts a fusible element. Another form utilizes bimetallic or linear expansion thermostatic elements. Still another form has a number of thermopiles assembled in series which when heated generate an operating current. The cold junctions of these thermostats being partially shielded, slow changes in temperature are ineffective, thus giving a "rate-of-rise" characteristic. Pneumatic types of rate-of-rise spot thermostats are also available.

A recent example of the effectiveness of automatic fire detecting service plus effective patroling and fire fighting service is the "Century of Progress" Exposition. Despite the flimsy character of the construction and the fact that 37,000,000 persons in

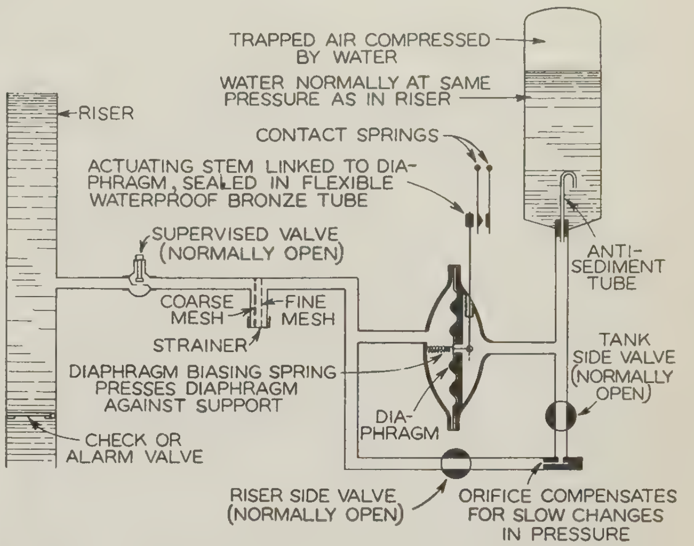


Fig. 3. A diagrammatic sketch of a differential pressure type of water flow detector

Increases in pressure, or slow decreases, have no effect. Sudden decreases in pressure as caused by the opening of a sprinkler head anywhere in the system, initiate an alarm

festive mood surged through the buildings and grounds, the fire losses were less than $5,000 for the 2 years. This is in striking contrast to the record of the Columbian Exposition in 1893.

Manual Fire Alarm Systems

To be effective, automatic fire alarm systems must cover the entire area to be protected. The somewhat higher cost of automatic systems provides a definite place for the manual fire alarm system in protecting large patrolled areas of less concentrated value. Manual fire alarm boxes on each floor of an industrial building offer good life and property protection by sounding local gongs to warn the occupants and simultaneously signaling a central station which calls the fire department.

Two types of local alarm systems are available, coded and noncoded. The former are further divided into the general alarm system which sounds all gongs for all alarms, and the presignal system which sounds its first alarm on "pilot" bells located in the superintendent's office or other designated places. After investigation, an authorized person can "condition" the fire alarm box to sound a general alarm. The presignal system is required for theaters, hotels, hospitals, and other public buildings where there is danger of panic.

Combination night watch supervisory and manual fire alarm systems are in common use. In these systems, the alarm box is arranged to transmit one round of signals when operated by the watchman's key, but to transmit from 4 to 7 rounds when oper-

ated by means of the pull-lever in case of fire. In proprietary systems the combination boxes are often equipped with a telephone connection and calling signal to provide communication means between the watchman and his supervisor.

Night Watchman Supervisory Systems

Night watchman supervision is important in that it removes the isolation which ordinarily exists and places the watchman in continuous direct-wire contact with an agency which checks his tour of the property, keeps him alert, investigates his delinquencies, and provides him with means of summoning immediate outside assistance in any emergency. As previously mentioned, watchmen may be checked by signals initiated on combination night watch and fire alarm stations. With such systems an attendant at the central office (or proprietary office) checks each code signal transmitted to see that all stations are "pulled" at the right time and in the right sequence. Devices are available which automatically "analyze" such signals and sound a warning signal in case of a delinquency.

Night watch systems which transmit signals only in case of a delinquency have been proposed but have not been commercialized because insurance underwriters prefer positive rather than negative signals. They require a signal from at least every tenth station visited. This requirement is met by a system having a maximum of 9 purely mechanical preliminary stations for each transmitting station. The transmitting station, shown in figure 6, cannot be operated until the watchman's key has been operated in each of the preliminary stations in predetermined sequence.

Fig. 4. A water flow detector operated by the movement of water in the pipe deflecting a flexible, hinged vane

A slight flow deflects the vane sufficiently to operate electrical contacts; greater flow flattens the vane against the inside of the pipe, offering very little resistance to water flow

Attempts to defeat the purpose of this system are indicated to the central station and investigated. Should an intruder compel the watchman to "ring in" on time in order to preclude outside investigation, he can readily transmit an emergency call without detection.

Miscellaneous Supervisory Systems

The supervision of automatic heating systems is among the more important of the miscellaneous supervisory services relating to fire hazards. Oil burners are supervised against flame failure, automatic stokers against the shearing of the safety pin on the fuel feed system, etc. Boilers are supervised against low water, high pressure, high temperature, etc. Rooms are supervised against low or high temperature or humidity. This latter service has quite a distinct field in cold storage vaults, curing vaults in various production processing, greenhouses, chicken hatcheries, etc.

The fine bore of the tubing offers such resistance to air flow that a break in the tubing affects the speed of fire detection only slightly

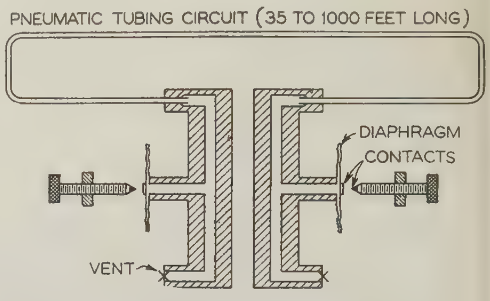


Fig. 5. The principal elements of a continuous, pneumatic, rate-of-rise, automatic fire alarm system

Other interesting applications of supervisory services are: transformer tanks against high temperature or pressure; the position of network switches or breakers; machinery against over-heating; etc.

Burglary and Robbery

A discussion of burglary and robbery protection requires an understanding of the nature of these hazards. The National Bureau of Casualty and Surety Underwriters define "burglary" as "an attempt forcibly to enter private property unlawfully for the purpose of gain." "Robbery," which in common parlance is termed "holdup," they define as "associated with an attempt to obtain securities or valuables from an institution or its representatives by threats of personal violence if resistance is offered," and "theft, although closely related to robbery, implies an attempt to steal property or valuables without threat of personal violence."

Burglar Alarm Systems

The Underwriters classify burglar alarm systems as:

1. Bank safe.
2. Bank vault.
3. Mercantile premises.
4. Mercantile safe.
5. Mercantile vaults.
6. Residence.

A "safe" is a portable, self-contained structure. A "vault" is an individually built-in structure.

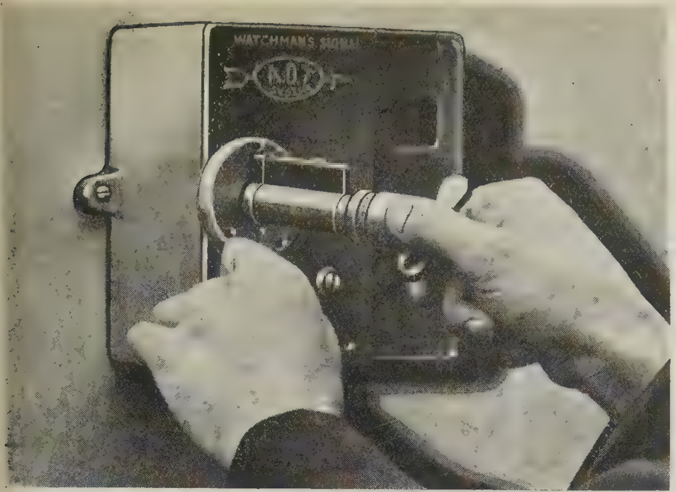


Fig. 6. The watchman's key of a suppressed signal night watch system being inserted in the transmitting station

A maximum of 9 purely mechanical preliminary stations, visited in predetermined sequence, set up the combination of the key to operate the transmitting station

Protection may be "complete" or "partial" according to the degree of coverage.

Safes or safe cabinets are protected by means of an enclosure, usually of wood lined with foil strips, built permanently around all sides except the front, which may be removable or fitted with hinged doors. Opening of the front or breaking into any portion of the enclosure breaks the foil circuit and initiates an alarm. In some cases the external enclosure is not used and the foil lining is installed on the inside of the safe.

Earlier practice has been to "lace" vault structures with lead covered insulated conductors on 3 inch centers embedded in the concrete at the time it is poured. These are under continuous electrical supervision and so arranged that any attempt at forcible entry will initiate an alarm by causing either a break, a short circuit, or ground. The expense of this type of protection, and the difficulty in applying it to vaults already constructed, are obvious from figure 7.

Present day vaults are protected by a sound actuated alarm system which is responsive to the noises resulting from attempts at forcible entry. False alarms, resulting from extraneous shocks and sounds, are overcome through the use of "sound accumulators" or retard elements which require a series of impulses to operate the system.

Vault doors are also protected against torch flames or electric arcs by heat actuated units installed in the vault door or vestibule. Alarm contacts are provided to indicate movement of the door and door bolts.

Mercantile establishments require a totally different type of protective equipment. Window glass is protected in most cases by narrow strips of foil which form a conductor for the electrical current. Screens constructed of wooden dowels containing hidden wires are also used for windows and doors. Similar wiring embedded in half-round wooden molding run in strips 3 to 4 inches apart is used to protect walls and ceilings. Floors are protected by wires laid in concrete or in wooden moulding with a false floor to protect against mechanical injury. The floor trap, an effective supplementary aid, consists of a thin flexible conductor of low visibility stretched across the protected area at vulnerable points which initiates an alarm when brushed against.

A new development consists of photoelectric units which serve the same function as floor traps but go further in their applications. It is possible under favorable conditions to cover as much as 300 feet with a single straight beam of practically invisible light. The introduction of mirrors for directing the beam around corners reduces the range sharply. This rating considers the utilization of but 20 per cent of the optimum light value, which allows for supply voltage variations, and the intervention of haze, fog, rain, and snow, and deterioration of the light source with age. Such equipment is not yet adaptable to complete premise protection because the modern burglar thinks nothing of cutting through wall, ceiling, or floor to reach his goal. Complete protection must not only guard against actual entry but also against "fishing." The impracticability of such complete protection by means of light beams is apparent, particularly when one considers the losses in the reflecting mirrors required for full coverage. However, partial protection of a group of windows or doors is feasible by means of a single beam directed parallel to them at the correct height on the inside of the premises.

The most practical application of light beam detectors is in the protection of out-of-door yards and areas, although false alarms may be caused by birds, animals, or wind-blown papers intercepting the beam.

Considerable development work has been done on protective systems actuated by the approach of a person whose body capacity upsets the equilibrium of a finely balanced electronic system. The limitation to really complete protection by such means is that in making it wholly effective to expert attack of a single person, it becomes so sensitive that false

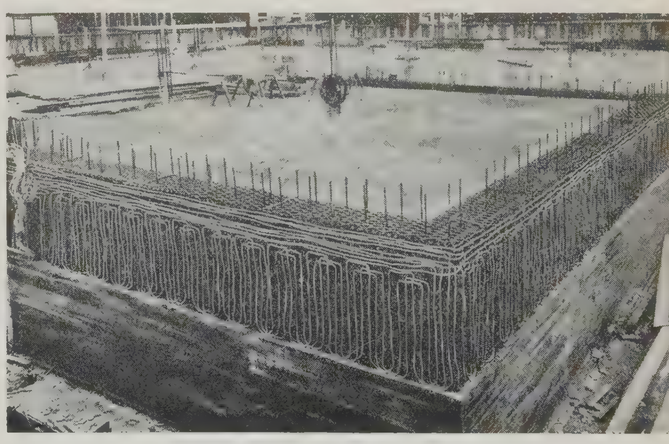


Fig. 7. A bank vault under construction, showing the protective "lacing" of several multicircuit cables embedded in the concrete

A break, ground, or short circuit between individual wires within the cable initiates an alarm

alarms may be initiated by one or more persons approaching the protected premises. This practically bars the utilization of such means for the protection of mercantile premises; it does hold some promise, however, for the protection of small safes, safe cabinets, and merchandise stock cabinets within the premises.

Other interesting possibilities which have been investigated for burglar alarm systems are pneumatic or atmospheric systems, wherein the opening or closing of doors or windows or even the entry of a

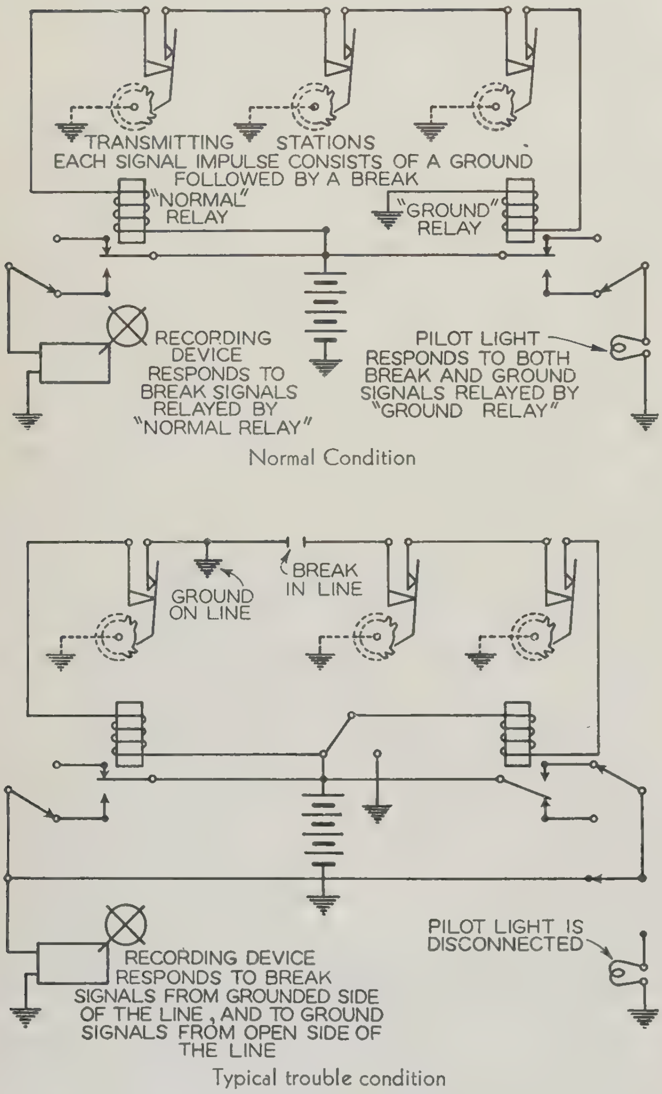


Fig. 8. The McCulloh circuit for transmission of coded signals to a central station or proprietary control desk

This circuit is self-supervised against breaks and grounds, and is rearranged by manual or automatic switches to transmit signals in spite of any break, ground, or combination of the 2

human body so disturbs the air in the room as to initiate an alarm. The great sensitiveness required and the effect of the infiltration of outside disturbances constitute problems of first magnitude in such developments. The possibility of using a thermal detector actuated by the approach of the human body has also been the subject of much investigation.

While these newer methods may present definite possibilities for covering certain portions of a risk or in providing some degree of partial protection, no cure-all has yet been found to displace completely the older methods which have proved their value over many years.

Holdup Alarm Systems

Robbery or holdup alarm service has many forms, but the main objective is to make it possible for the victim to initiate a silent alarm without the knowledge of the robber who invariably cautions against an outcry or alarm. The fear of reprisal, of course, discourages many from utilizing available alarm facilities. Alarm initiating stations have been developed which make it possible to summon outside aid inconspicuously while actually following the commands of the robber or even by permitting the robber himself to initiate the alarm. Connections to a central station or a nearby vigilante station instead of to an audible signal outside the door render the alarm silent and eliminate the fear of reprisal. Use of police radio broadcasting facilities with cruising patrol cars ready for immediate response has measurably increased the value of central station holdup alarm systems during the past few years.

Circuits

With most electrical systems simplicity and directness of operation is desirable but with burglar alarm systems they are purposely complicated by providing feed backs, multipaths, electrically balanced elements, dummy conductors, etc., and the avoidance of any identifying means on terminals or conductors. For obvious reasons the detail of such arrangements are not being disclosed.

Grade *A* burglar alarm and holdup alarm systems are connected to a central station by a private wire to each subscriber, so circuited that a break, ground, short circuit, or change in resistance will initiate a signal. Other burglar alarms and the protective systems heretofore mentioned are usually connected to the central station by means of a series loop circuit to which several subscribers may be connected.

Central station loop circuits are operated on the McCulloh principle illustrated in figure 8, which permits transmission of signals despite a single break or ground or a combination of a break and ground. This is accomplished by having the code wheel on the transmitting device arranged to send the code signal in "break" impulses and in "ground" impulses. Under "normal" and "ground" conditions the "break" impulses are recorded. With a broken line, the "ground" impulses are recorded. The switching which is necessary to meet these different conditions may be accomplished manually or automatically.

All code signals transmitted to the central station are recorded on a paper tape by means of inking registers. A storage battery with suitable stand by facilities provides energy for all central station circuits. The entire central station equipment is in-

stalled, operated, and maintained in accordance with the Underwriters' requirements.

A new type of central station which is practically automatic in its operation has recently been established in Utica, N. Y. Automatic selection equipment on each circuit accepts and records all signals as they come in and routes them properly for such further attention as they should receive. Thus a fire or waterflow sounds a special attention signal at the central station and the alarm is simultaneously transmitted to fire headquarters. Similarly an emergency call, burglar alarm, or holdup alarm would be transmitted to police headquarters. Sprinkler supervisory and watchman's delinquency signals sound the special attention signal. Routine night watch signals are merely recorded.

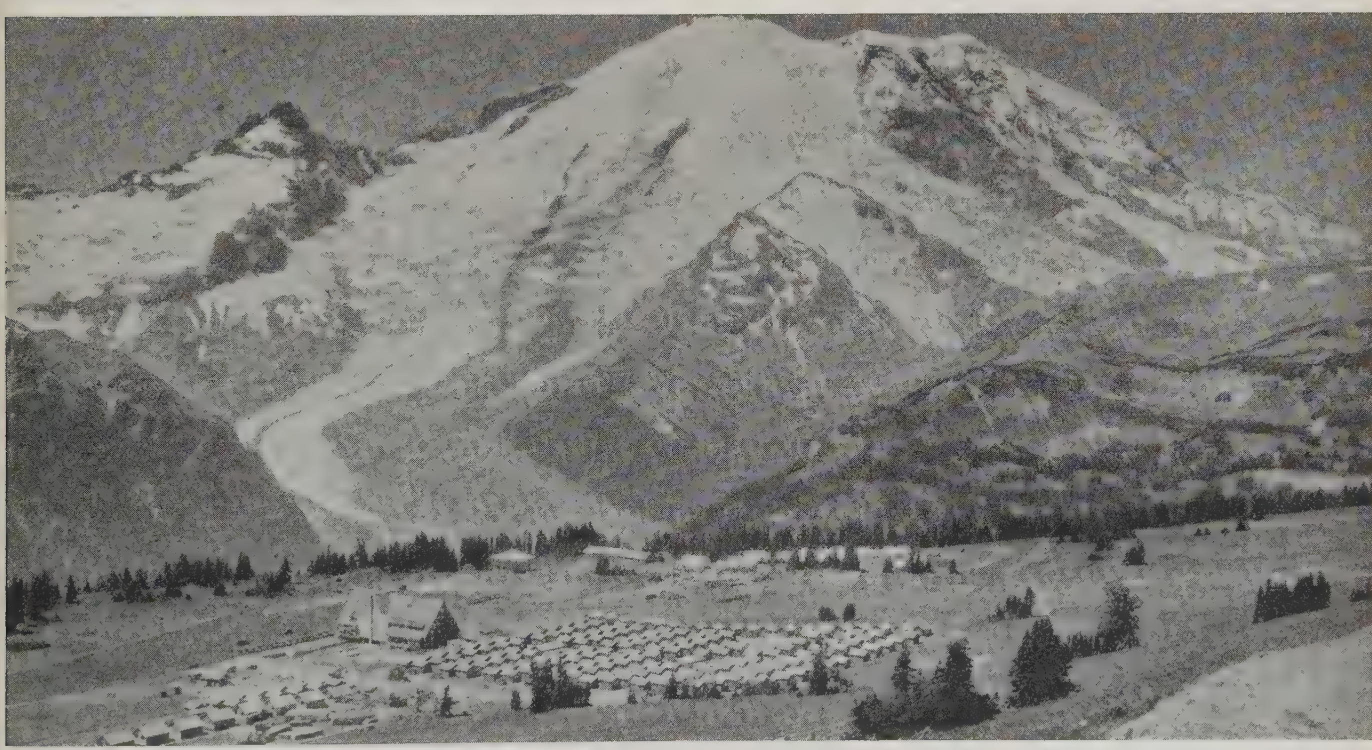
Considerable study has been given to the possibility of transmission to central stations through the use of short wave radio. The complications arising from licensing transmitting stations at each subscriber's premises, together with the Underwriters' antipathy to systems less positively supervised than present land line circuits are definitely against such practice. This latter point applies also to carrier current transmission which has been given considerable study.

Proprietary Central Stations

Proprietary central stations are usually equipped similarly to those of the commercial operating companies. A new type of proprietary central station includes an annunciator with a simple multiple circuit to actuating contacts on each device or station being covered. The associated "drop" instantly indicates any activity at that station. Each annunciator "drop" is connected to a selector and through it to a transmitter which causes the corresponding signal to be recorded on an automatic printing recorder. This device transposes the code signals into printed figures and words indicating the source of each alarm and the time of recordance. The arrangement is such that these recordings are noninterfering and successive. A further feature is that fire alarms, for instance, are given preference over supervisory signals in the order of recordance.

Another type of proprietary equipment makes use of a separate unit transmitter at each device or station. This system operates over a 3 wire loop. The transmitters are energized from a central power source. Their operation is noninterfering and successive. The system will operate with a "break" or "ground" anywhere on the loop. Even if the cable is completely severed, it will still operate and preserve the noninterfering and successive feature.

In this discussion it has been attempted to give only a general outline of the application of electrical protection of life and property. Though the subject of protection against fire and burglary is, of course, a very old one, many new angles are constantly being projected into it by new hazards resulting from the complexity of modern living, and the ingenious audacity of the modern crook, all of which contribute greatly to the interest and possibilities in this field of protective signaling.



Sunrise Lodge and cabin area on the north side of Rainier National Park with Mt. Rainier in the background, which may be reached by a scenic highway but 2 hours from Seattle, Wash., scene of the Institute's 1935 Pacific Coast convention to be held August 27—30. Emmons Glacier, largest of the 28 glaciers on the mountain, may be seen winding its way down the snowy slopes

Insulation for High Voltage Alternators

Recent developments in mica tape insulation and stator winding construction for a-c rotating machines of large capacity wound for standard and appreciably higher than standard voltages are considered in this paper. Methods of improving composite mica tape insulation are discussed and the advantages of graded insulation are considered. Two types of windings for graded insulation are proposed for 33,000 volt machines. Special designs involving the insulation and construction of the end windings are presented, and methods of avoiding corona in the end winding zone are analyzed.

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THE development of improved insulating materials and of new methods of stator winding construction in recent years has opened the way for the construction of large capacity a-c rotating machines of higher voltage rating than are ordinarily in use in the United States. Furthermore, the difficulties involved in handling alternating currents of large magnitudes at the generating stations emphasizes the need for larger capacity generators of 27,600 to 33,000 volts rating.

As a result of the recent developments described in this paper, which include not only new insulating materials having promising characteristics, but also new methods of applying the insulation and in constructing the stator coils, the following general conclusions may be drawn:

1. The breakdown strength and dielectric loss of mica tape insulation have been improved materially by developing a bonding compound with more desirable characteristics, by exercising more effective control of the quality of the component materials, and by improving manufacturing processes for making the tape and applying it to coils.

2. Present mica tape insulation is adequate for stator windings of 33,000 volt generators. By using graded insulation (i. e., heavier insulation on the coils subjected to the higher voltages than is used on the coils near the neutral) on the stator winding of such machines, the costs can be reduced materially without any sacrifice in winding reliability, provided an arrester is installed at the junction of the 2 insulations. Two types of windings are available for building 33,000 volt machines with graded insulation. With one type corona can be eliminated at normal voltages, whereas with the other it can be eliminated at approximately test voltage.

3. Specific methods of end winding construction have been investigated and are proposed as adequate solutions for avoiding corona discharges between end winding conductors of different potentials, and creepage over the conductor surface to ground.

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General Discussion of Insulation Problems

The operating records of companies engaged in the generation and consumption of electrical energy and the records of companies which provide insurance coverage for dynamo machines classify the majority of the troubles on motors and generators as winding failures. However, an analysis of these data indicates that the larger percentage of the troubles is confined to relatively small industrial types of machines, which generally do not have mica insulation on the stator windings and which are subject to either unfavorable operating conditions or are given inadequate maintenance. Of the failures properly chargeable against large capacity machines in which mica insulation is used, the larger portion is on the field or excitation winding, in which the voltage is relatively low. The actual number of failures on stator windings on this class of machines is small and is appreciably lower at the present time than it was 15 to 20 years ago. The decrease in stator winding failures on the large capacity machines can be attributed to an improvement in the quality of insulation furnished by the manufacturer; a reduction in operating temperatures; operation with the closed circuit system of ventilation; and more effective protection from lightning and switching potential surges. It is anticipated that stator winding failures will occur still less frequently when more complete insulation co-ordination practices are adopted.

It has been recognized practice for a number of years for the manufacturer to determine the amount of insulation deemed necessary and sufficient for any given standard voltage. The actual thickness of insulation used by each manufacturer for a given voltage has been determined from the operating experience with machines over a long period of time. An increase in the insulation wall thickness for a given voltage would result in a larger and more costly machine. It rarely occurs that a purchaser specifies a greater amount of insulation than that normally required for the voltage class under consideration. In view of the fact that there are relatively few stator winding failures on machines with mica insulation, and that the purchasers do not feel justified in increasing the investment expense for an increased amount of insulation over that normally furnished, it can be concluded that the present mica insulation and insulation thickness standards are satisfactory at least for present standard voltages. It can be

concluded further that purchasers are not interested in better insulation performance for this class of machines, unless the improvement can be obtained at a cost comparable with the cost of obtaining the equivalent improvement from improved operating schedules, better maintenance, and more effective protection. Both manufacturer and purchaser are mutually interested in improvements in insulation which can be obtained without an increase in the cost of the product.

A relatively large number of new materials and compounds have been developed during the past few years. Some of these products, such as the new resins derived from rubber, synthetic waxes, cellulose acetate, cellophane, and solventless compounds, have promising characteristics for insulation applications. A few of these materials have actually been applied as insulation on magnet and general purpose electric conductors. The use of these new materials as bonding and carrier elements in the construction of composite mica insulation deserves consideration. The writers of this paper in conjunction with other associates have been investigating the properties and characteristics of these materials, alone and as fabricated composite mica insulation, in order to keep the insulation development apace with that of materials and with the general improvements in the design of the electric and magnetic circuits and structural parts.

Functions of Insulation

The primary function of insulation on the stator winding is to confine and direct the flow of electrical energy along prescribed channels so that the maximum useful input to or output from the unit can be obtained. Not only must the insulation withstand the potential stresses imposed upon it, but the amount of corona at normal operating voltages should be kept small. With the closed circuit system of ventilation, the continuous discharge of corona from the stator winding is more objectionable than in the case of the earlier unit which was continuously provided with a fresh supply of cooling air. The resulting increasing amount of nitrous oxide which is retained in the enclosure, in the presence of an excess amount of moisture, forms weak acids which attack the fins and tubes of the air cooler and deteriorate the organic insulation on the end-winding connectors, paralleling rings, and bracing members. In the case of older machines, the straight part of the coil in contact with the stator iron was the principal source of corona. This source of corona has been eliminated by applying asbestos tape to the straight part of the coil, treating to make it semi-conducting, and permitting this semi-conducting surface to be in direct contact with the stator iron. The remaining parts of the stator windings can be made practically corona free at normal voltages by grading off the resistance of the coil surface beyond the end of the core and properly spacing the coil ends.

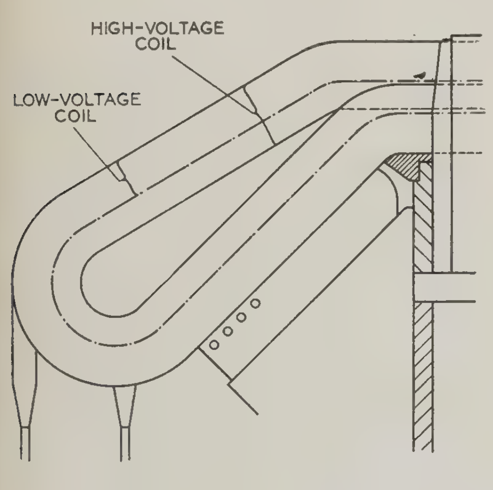


Fig. 1. A method of providing graded insulation for stator windings by using standard types of coils of rectangular cross section, with 2 coil sides per slot

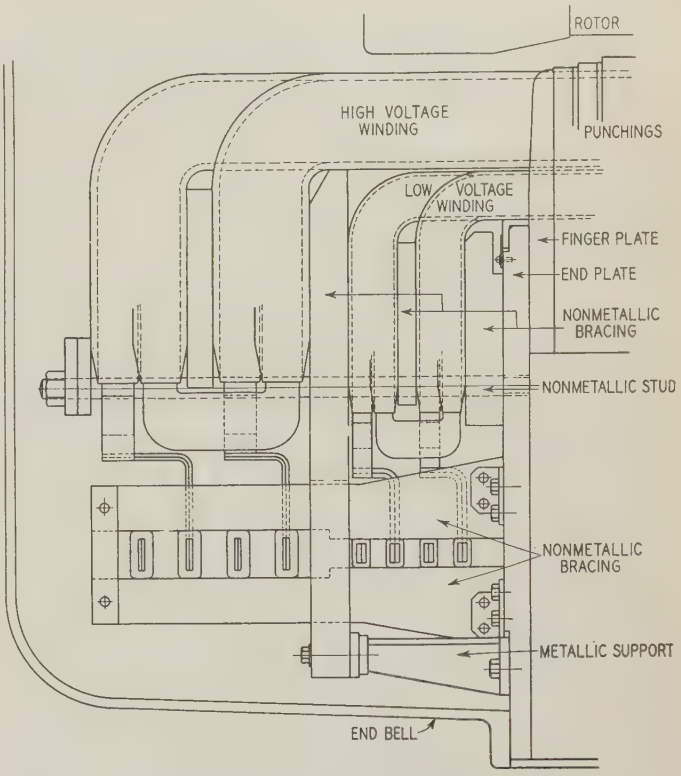


Fig. 2. A method of providing graded insulation for stator windings, by using 2 superimposed single layer windings

The problem of increasing the average breakdown strength of composite mica insulation is augmented by the fact that fundamental theory for and data on the mechanics of breakdown are not available. Until this kind of information is available, it will be impossible to determine the most effective procedure to follow in making insulation improvements. It is logical to expect that the fundamental concept and knowledge of insulation characteristics and limitations should be known sufficiently well that the quality of the insulation could be determined quantitatively from insulation test specimens taken from any section of a completely insulated coil. Although a rather limited effort is being made to obtain fundamental data on composite mica insulation, it is felt that the problem is of sufficient importance to

justify an even wider consideration by the research departments of some of the better equipped technical schools and universities than is being given at the present time.

Tests on Composite Mica Insulation

Composite mica insulation consists of the mica splittings, a mechanical carrier such as paper, cloth, cellophane, or other materials, and a bonding compound for cementing the mica splittings to the carrier, and adjacent layers of insulation to each other. The investigation to improve this type of insulation involved 3 principal items, namely, investigation of the characteristics of suitable materials for bonds and mechanical carriers; development of methods and processes for fabricating the insulation and applying it to stator coils; and an investigation of the characteristics of the insulation when applied to bar samples and actual coils. In comparing the bonding materials, high breakdown strength, low dielectric loss and good adhesiveness are the most vital factors. From the test data obtained on a large number of test specimens with different kinds of bonds, the following generalizations can be made: on step-by-step tests under oil, in which the voltage is raised in steps of 5 kv at the end of each minute, the puncture strength seems to depend almost directly upon the dielectric loss; and on short time tests where the voltage is raised quickly, and at an approximately uniform rate to failure (say in 10 to 30 seconds to failure), the absence of air pockets in the insulation seems to be the most important attribute. Power factor, or more correctly dielectric loss, seems to furnish one measure of the quality of the material used.

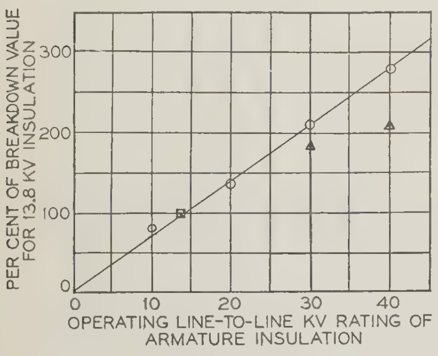


Fig. 3. Short time breakdown data for copper bars of different shapes and insulated for different voltage ratings, based upon tests made under oil on new mica tape

Circles—Tests on 1/2 by 3 inch rectangular copper bars insulated for voltages indicated. Protected against corona by shielding

Square—Average of tests on large number of rectangular bars

Triangles—Tests on 1/2 by 3 inch copper bars with semi-circular contour at top and bottom edges. Protected against corona by shielding

For comparing built up coil samples using different mica bonds, the dielectric losses at elevated temperatures give a measure of the relative abilities of these different armature insulations to withstand long-time or step-by-step over-potential tests. In this connection, where thermoplastic materials are used, it is well to note that the losses increase rapidly once the "melting" or softening zone is reached, yet the hardness and tendency to brittleness at room temperatures must also be considered, so that a reasonable balance must be arrived at in selecting the mica bond.

As between different built up insulations using the same mica bonds, power factor against voltage at a given temperature can be used to give a measure of the relative presence or absence of voids, because when the voltage is reached at which internal corona starts, the power factor increases much more rapidly with voltage than at the lower voltages. Power factor or loss measurements can be used to show the average condition of the insulation on individual stator coils, and thus can serve as a check on the quality and uniformity of materials and manufacturing processes. However, it cannot be concluded that such measurements can be relied upon definitely to determine the breakdown value of a particular coil because local inperfections may not show up sufficiently large in the dielectric loss values, even when relatively small effective electrodes are used and special precautions are exercised in making the measurements. Dielectric loss measurements are being made at different voltages on coils as they come through on customers' orders, to determine whether the relation between dielectric loss and breakdown strength can be used as a quality check on insulated coils during normal manufacturing operation. In checking the variations in the dielectric loss of the insulation on a coil, it is necessary to make the loss measurements on relatively small incremental lengths and traverse the entire coil. With the most up-to-date equipment available, an appreciable amount of time is required for each loss measurement, and thus considerable time and expense are involved in covering the entire coil. If the results from the present investigation indicate that dielectric loss values can be used as a reliable measure of insulation breakdown strength for finished coils, it will be necessary to develop special electrodes and reliable indicating or recording measuring equipment so that the data can be obtained economically for an entire coil and not handicap production.

It is well to consider at this point the possible uses of dielectric power factor measurements on machines already in service, to determine the quality of insulation. In the first place, these older machines do not have semi-conducting materials on the outside of the coil surface, so that on such windings dielectric loss readings will be affected by the small air spaces between the coil surface and the iron, and thus the data will not be a fair measure of the quality of the insulation. On the newer machines with semi-conducting materials to ground the coil surfaces to the punchings, it is quite probable that a technique can be developed whereby dielectric loss measurements on the insulation will tell much about the average condition of the insulation. The development of this technique should be undertaken jointly by the operators and insurance engineers who have the service experience, and the manufacturers who have spent much time on all phases of fabricating built-up insulation.

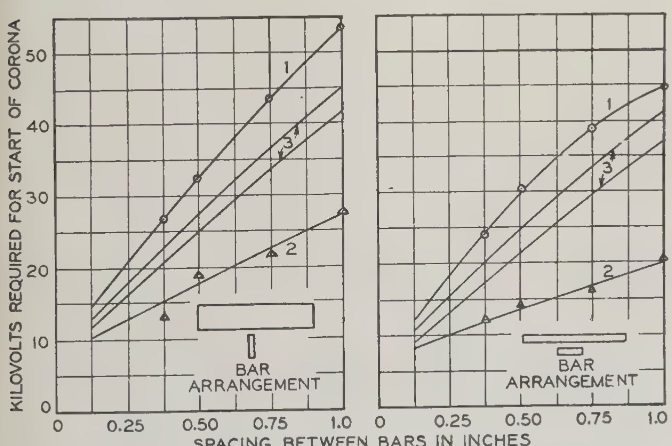
Up to date, the effort put forth on this insulation

development program has resulted in a material improvement in the average breakdown strength and dielectric loss of mica tape insulation by using a bonding element with more desirable characteristics; controlling the quality and condition of the component materials; and improving the technique of making the tape and applying it to coils. Although the improvements in mica tape insulation are of importance for stator windings at both standard and appreciably higher than standard voltages, the search for a bonding element with dielectric, thermal, and mechanical properties more nearly approaching the ideal requirements, is being continued.

Increased Voltages for A-C Generators

In the United States a number of generators have been built for potentials of 16,500 to 24,000 volts. There has been no marked increase in the magnitude of the generated voltage during the past 5 years. In Europe, the number of turbogenerators built for direct generation at 33,000 volts is steadily increasing. The disadvantages and difficulties associated with switching equipment, cables, and station structures[10] in handling alternating currents of large magnitude, emphasize the importance and need for building larger capacity generators for voltages of 27,600 to 33,000 volts.

Generators wound for voltages appreciably higher than the present standards are larger, longer, and more costly than units wound for the most economical voltage, which is usually nearer the standard voltage value. All of the high voltage generators built in the United States have had the same insulation on all of the coils, whereas in Europe practically all of the 33,000 volt generators have had the



Figs. 4 and 5. Voltage required for start of corona, for 2 different bar arrangements

Fig. 4 (left)—Bars crossed edgewise at 90 degrees

Fig. 5 (right)—Bars crossed flatwise

For both bar arrangements, bars were $^5/_8$ by $3^1/_4$ inch copper bars insulated for 13,800 volts with mica tape and finished as follows:

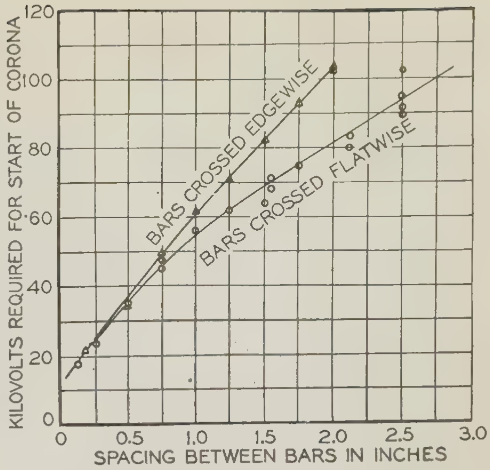
1—Butted treated cloth tape sanded and varnished 5 times to get smoothest possible finish

2—0.015 inch asbestos tape specially treated to make it electrically nonconducting but not made smooth

3—Commercial range

Fig. 6. Voltage required for start of corona, for 2 different bar arrangements

For both arrangements, bars were $^5/_8$ by $3^1/_4$ inch copper bars insulated for 33,000 volts, with mica tape finished as for a commercial machine



stator coil insulation graded in 2 or more steps in progressing from the neutral to the terminal leads. In connection with the increase in weights, dimensions, and costs of the high voltage generators with graded insulation, consider a machine having the armature winding insulated throughout with one wall thickness equal to the average of the various insulations to ground of another machine insulated with graded insulation. If these 2 machines are of equal kilovoltampere ratings and speeds, they will have approximately the same weights, dimensions, and cost.

The performance characteristics of stator windings with graded insulation differ from windings with uniform insulation only in regard to the over-potential tests and protection against over-potential surges. In making over-potential tests, each of the 2 windings will have to be tested separately at a potential corresponding to its class of insulation. In order to protect the winding with the reduced amount of insulation against over-potential stress to ground, an additional arrester is required at the junction between the low and high potential windings.[7,9] The cost of the additional protective equipment required by the high voltage generator with graded insulation is relatively insignificant as compared to the reduction in the cost of the generator. From the standpoint of generator costs and dimensions, the use of graded insulation is a very attractive proposition and deserves serious consideration by the purchasers of high voltage generating equipment.

Two methods of providing graded insulation for stator windings have been investigated by the writers of this paper and are offered as practical solutions to the problem. The first is a by-product of the double winding development for a-c generators. (This type of winding was proposed by C. W. Guth of Westinghouse Electric and Manufacturing Company.) The winding uses the standard type of coils with rectangular cross section for open slots as shown in figure 1. In each slot there are 2 coil sides, one insulated for full generated voltage and the other for half or approximately half terminal voltage. The coil sides are placed alternately in the top and bottom of the slots for alternate slots or alternate groups of slots. The respective coil sides of each insulation grade are connected in series and the

1. For all numbered references see list at end of paper.

leads brought out for 2 independent windings, one insulated for half or approximately half voltage and the other for full voltage. The 2 windings are connected in series to develop full voltage, with the low voltage winding located nearest the neutral. The coils of the 2 windings will be of the same width but may or may not be of the same depth. This type of winding introduces no new difficulties in assembly, coil end bracing, inter-coil connections and end turn insulation. Its principal limitation is that large clearances cannot be obtained economically between phase conductors on the end turns. However, it is usually possible to obtain sufficient clearances so that no corona will exist on the end windings at normal voltages.

The second winding development for graded insulation consists of 2 superimposed single layer windings as shown in figure 2. The winding in the bottom of the slots is insulated for $^1/_2$ normal voltage and the one at the top for full voltage. The windings are normally approximately full pitch, and further chording effects are obtained by displacing one winding circumferentially with respect to the other. This arrangement of the windings gives twice the center to center spacing between coil sides in any conical layer and approximately 3 times the air spacing when compared to the conventional 2 layer winding. With the greater separation, it is possible to build 33,000 volt generators which are essentially free of corona at the final test voltage of twice normal plus 1,000 volts. This problem will be discussed later in the paper.

Special Design Problems

The special problems involved in the design of high voltage rotating machines naturally fall into 2 separate groups, namely:

1. Those problems which are introduced by the possibilities of connecting high voltage machines directly to overhead lines so as to reap the fullest benefit of such higher voltage apparatus where this is possible. This phase of the subject has been adequately discussed in earlier papers[5-9] and, consequently, will not be considered in this paper.

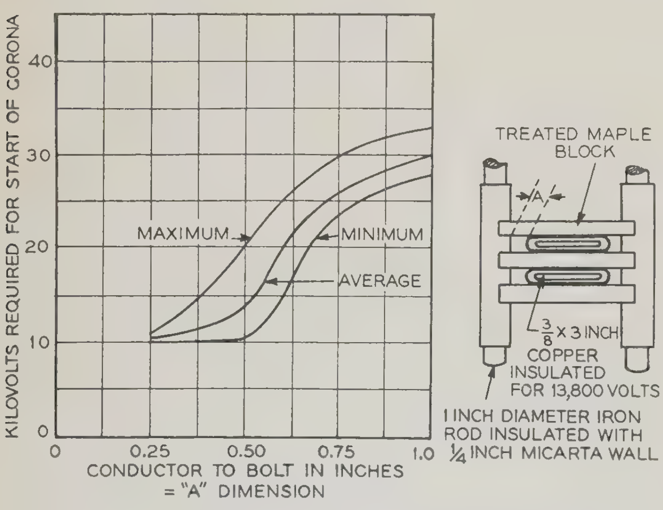


Fig. 7. Model of phase connecting rings and supporting structure; showing voltage required for start of corona, versus distance from conductor to bolts for 13,800 volt insulation on the connecting rings

2. Those problems which are introduced by the use of higher generated voltages (22 kv to 33 kv) which cannot be solved by ordinary design methods.

Under the second group there are again 2 main problems. The first is to design a slot insulation to obtain the minimum space occupied by the insulation, yet sufficient to withstand the over-voltage tests. The second is to design the end windings and the end winding insulation so that trouble due to corona or electrostatic discharges will be avoided.

Design of Slot Insulation

In higher voltage rotating apparatus, 22 kv and above, the slot insulation begins to occupy a very large percentage of the slot-tooth zone of the stator core. It obviously becomes desirable and necessary to use as few slots as possible without introducing excessive iron losses in the stator teeth and in the

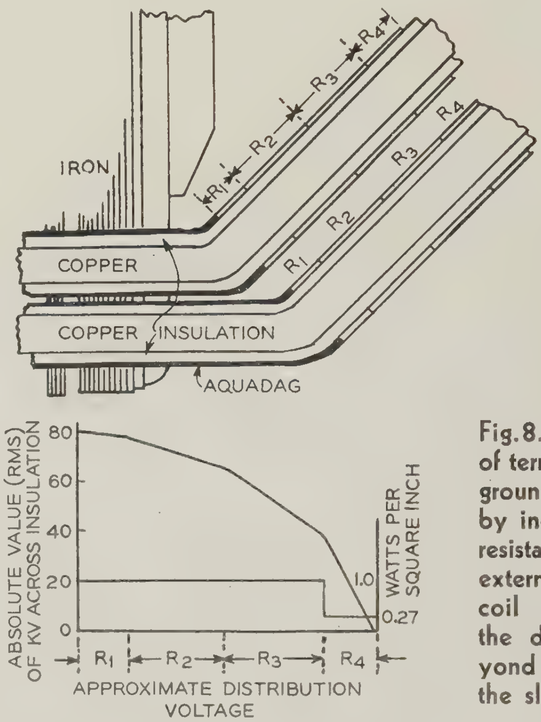


Fig. 8. A method of terminating the grounding surface by increasing the resistance applied externally to the coil surfaces as the distance beyond the end of the slot increases

surface of the rotor. The use of fewer stator slots facilitates the solution of end winding design, as will be shown later. It is also apparent from the standpoint of economy in the use of materials that the amount of insulation must be held to a minimum compatible with the insulation requirements.

An analysis of the general problem of electrostatic stress concentrations in rectangularly shaped coils for high voltage generators and methods for reducing the stress concentrations have been considered in a previous paper[4] and these features will not be discussed further. The curve in figure 3 shows the breakdown strength obtained on bar samples with square corners for insulation thicknesses corresponding to 10,000, 20,000, 30,000, and 40,000 volts and for 2 bars with half-round edges insulated for 30,000 and 40,000 volts. It was expected that the bars with the half-round edges would have a higher breakdown strength than those with square corners.

Fig. 9. A second method of terminating the grounding surface beyond the end of the slot by the use of an end shield with internal semi-conducting sheaths only

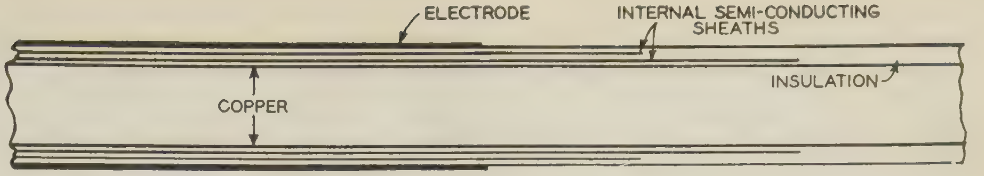
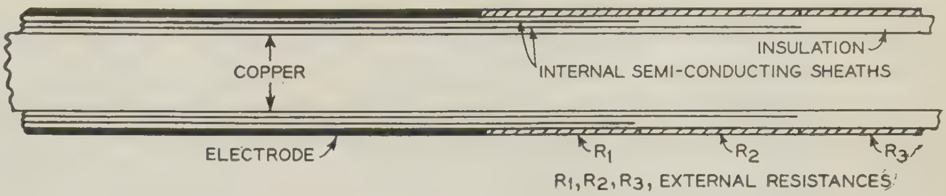


Fig. 10. A third method of terminating the grounding surface by using an end shield with internal semi-conducting sheaths and also external resistances, thus combining the methods shown in figures 8 and 9



The bar with half-round edges insulated for 40,000 volts had flashed to ground at 160 kv previous to the breakdown test and this may account for the decreased breakdown strength. These test results indicate that electrostatic stress concentration is not a limiting factor in the performance of well built mica insulated coils of conventional design for voltages well above any value considered feasible at present. The satisfactory operating records of 16,500 to 24,000 volt generators in service in the United States, and the added knowledge that has been obtained on the performance characteristics of composite mica insulation on bar samples, gives assurance that the present mica tape insulation is entirely adequate for higher voltage windings. It is obviously desirable and necessary to give more care and supervision to the manufacture of the insulation and its application to the coils, handling the coils through the respective manufacturing processes, assembling the coils in the machine, making insulation tests, and conditioning the machine prior to going into service.

Design of End Windings

The next major problem is the design of the end winding for the elimination of corona. These problems are by far the most difficult to overcome in the design of high voltage machines. There are 2 types of discharges to be guarded against, namely, discharge directly between 2 conductors, as between adjacent coils of different phases, and creepage to ground over the surface of one conductor.

Before considering the design possibilities, it is well to note some of the physical phenomena which affect the discharge between coil sides. Humidity up to the dew point has very little effect, perhaps 10 per cent at the most. Temperature and pressure variations existent in ordinary machines have a negligible effect. Ionized air left from a preceding test may reduce the discharge voltage on a test made almost immediately following, by as much as 10 per cent. The most important factor is roughness. In extreme conditions, this can cause a variation of 2 to 1. These data were obtained by visual observations in a specially made dark room. The voltage value at which corona was first faintly visible was used and was checked individually by several observers. All values were taken at 60 cycles on an increasing voltage, and several readings were taken for each point. See figures 4 to 7, inclusive. Thus, humidity, air density, and previous ionization have small effects, while surface roughness, by furnishing small points from which discharge may start, is by far the most important practical feature.

Of the several methods available for raising the voltage at which corona will start in the air spaces between conductors, the most promising are: (*a*) to apply a conducting or a semi-conducting material to the external surface of the coil ends which will act as a relatively low resistance shunt to ground in parallel with the intervening air; and (*b*) to increase the air gap spacing.

The proposition of applying a ground sheath of semi-conducting material over the entire winding to the machine terminals, or to points in the end winding where adequate separations are attainable, is the most desirable solution of the problem due to the fact that it simplifies the stator winding end construction and bracing, reduces the spacing requirements between coils, and thus results in a reduction of the axial length of the coil extensions. All of these advantages contribute to a reduction in the over-all length and cost of the unit. With the external coating of semi-conducting material on the end turns, the insulation must withstand approximately normal ground potential that exists for each particular coil, and the semi-conducting surface material must conduct the charging currents to ground without overheating. The corona problems thus become insulation and surface conduction problems. Therefore, it becomes necessary to make the end turn insulation as effective as that on the straight part of the coil. This is difficult to accomplish because the contour of the end turns is such that it is hard to apply the insulation so that it is free of air voids. In order to obtain the required insulation strength, it would be necessary to apply more insulation, desirable to find a more satisfactory bonding material, and essential to develop manufacturing methods and processes for applying the insulation to curved surfaces so that the final insulation is solid, free of voids, and reasonably flexible at normal operating temperatures.

In the case of large capacity, high speed turbogenerators which can be designed with relatively large stator slot pitches, it usually will not be necessary to take special steps in designing the end wind-

ings, to avoid corona at normal voltages. With this class of machines the special type of the conventional 2 layer winding, previously discussed in an earlier part of this paper (see figure 1) can be used satisfactorily. For lower speed machines in which sufficiently large slot pitches cannot be obtained economically, it will be necessary to use the 2 single layer type of winding as previously described and as shown in figure 2. With this type of winding, corona discharges can be avoided at approximately the final test voltages. It is obvious from figure 2 that this type of winding requires long end turn extensions, with rather elaborate bracing, both of which result in an increase in the size and cost of the unit.

At some point along the coil surface in present day designs, the grounding surface terminates. At present this is only a slight distance beyond the end of the slot. At this point something must be done to prevent excessive voltage gradients which will result in corona discharges along the surface of the coils.

Two or 3 methods present themselves for the solution of these difficulties. One of these is shown in figure 8, where, reading outward from the slot iron, successively increasing resistances are applied to the coil surfaces. The case shown is the electrical equivalent of 4 miniature cables connected in series. There is distributed resistance on the coil surface, distributed capacitance to copper through the insulation, and at 60 cycles, negligible inductance per unit of length. The voltage distribution may be calculated exactly as would be done for the cables. Semi-conducting paints have been developed, and

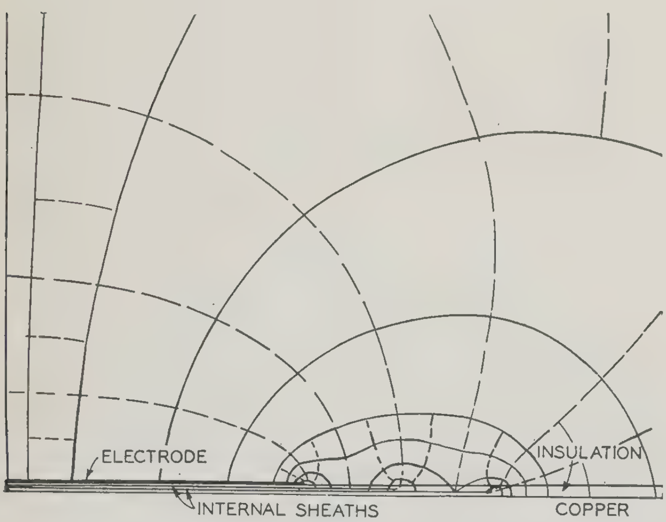


Fig. 11. A 2 dimensional flux map used for obtaining a simplified solution for the voltage gradient beyond end of slot, with internal sheaths but not external resistances

such a corona shield built which was capable of sustaining test voltages up to 70 kv with no corona or serious heating on a one minute test.

Another possibility is shown in figure 9, in which internal sheaths are used as in the case of condenser bushings, except that the sheaths are of semi-conducting instead of metallic materials. An experimental design similar to this has been built successfully for test voltages up to 90 kv. It is undesirable for a given voltage to use as many of these sheaths in armature insulation as are used in condenser bushings. If a sufficient number of sheaths are not used, the voltage gradient is not as uniform as it should be.

This difficulty can be overcome by a combination of these 2 schemes, as illustrated in figure 10. By means of a 2 dimensional flux map (figure 11), a simplified solution is obtained for the voltage gradient with internal sheaths, but no external sheath. The calculated distribution with external resistance added is shown in figure 13. A shield of this kind built with a total length of 24 inches plus 18 inches

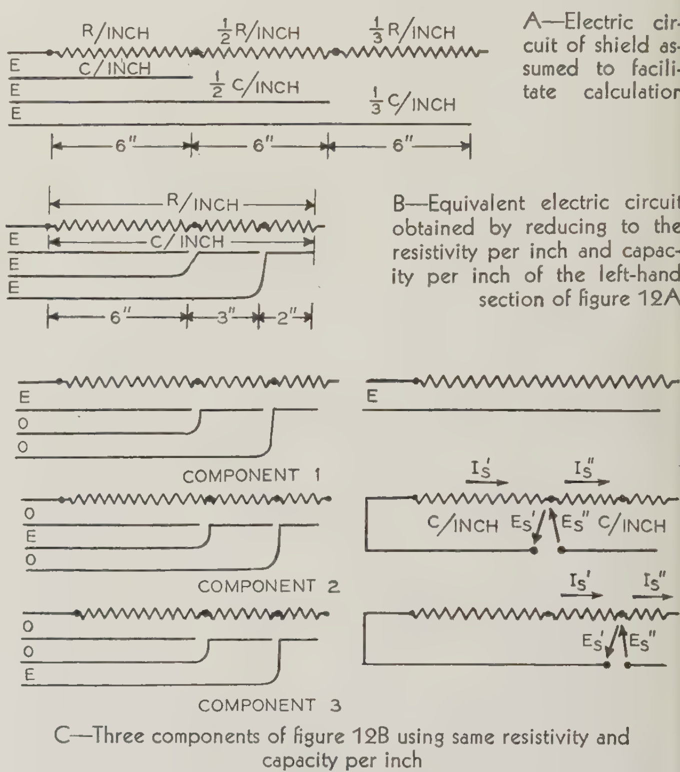


Fig. 12. Equivalent circuits used in calculating values of external resistance beyond end of slot for the end shield of figure 10

free creepage distance at the ends, when tested in air, withstood 155 kv without corona and flashed over at 160 kv, as mentioned above.

Appendix—Design of End Shield

It is intended in this appendix to discuss in somewhat more detail, methods for designing an end shield similar to that shown in figures 9 and 10.

The shield shown in figure 9 will be discussed first. These internal sheaths act similarly to those in a condenser bushing. In this case, they must be extended sufficiently well into the slot zone that they will take on very approximately the potential corresponding to their relative location in the insulation between the copper and iron. It is desirable to use as few sheaths as possible to avoid sacrificing too much space which otherwise would be used for insulation.

Figure 13 shows the voltage distribution expected with such a

shield in comparison with the voltage distribution when no shielding is used. Figure 11 shows the approximate electrostatic field for the shield of figure 9. Two-dimensional boundary conditions and a single dielectric constant assumed for both insulation and air, introduce definite discrepancies. However, these simplifying assumptions should not introduce very large errors, and the calculated distribution should be somewhere near the actual.

An interesting feature in this map (figure 11) is the manner in which the potential surfaces leave the semi-conducting sheaths fairly well back from the outer ends. This results in a fairly high density at the outer end of the embedded sheaths. It is probably desirable to use fairly high resistivity material at least at the ends of these sheaths. However, in drawing figure 11, the sheaths were assumed to have no appreciable voltage drop along them. The justification for this will be brought out later.

This brings up the question of the resistivity which should be used in these sheaths. Obviously, a solid sheet of metal foil could not be used, because the electromagnetic flux would set up eddy currents in it which would result in excessive heating. A wire or very thin ribbon could be wound on in a spiral to overcome this difficulty. However, possible air pockets and certain electrostatic stress concentrations within the insulation make these solutions doubtful. Therefore, semi-conducting paints were developed with which in a thin coat of suitable material practically any resistivity from a few ohms to infinity could be obtained for the surface resistivity per square inch of surface.

To calculate the desired resistivity, the largest desired voltage between layers was assumed, and the resistivity of the sheath taken as zero for the moment. From this, the maximum possible charging current from the overlap of one sheath to the next inner sheath was computed for test voltages. The resistivity was then so determined that with this current the temperature rise in 10 minutes was only about 4 degrees centigrade. To simplify this computation, the insulation can be treated as infinitely thick, because only a small amount of heat will reach the outer surface in 10 minutes. The details of this calculation will not be given. It is only necessary to know the heat conductivity and the heat storage capacity for the insulation and to use well-known methods of calculation (see page 294 of reference 2). The current and resistivity determined for the internal sheaths by this method of calculation are such that the assumption of no very large voltage drop along these sheaths becomes justified.

Calculation of Voltage Distribution

By referring to figure 13, it will be observed that the voltage distribution is greatly improved by means of the internal sheaths, but it is not all that might be desired, due to the rather steep gradients at certain points. It is probably sufficiently good for most commercial tests on high voltage coils, but should be improved so as to prevent flashovers or severe static up to the puncture voltage.

Continuous and connected layers of semi-conducting paints of suitable resistivities applied to the outside surface will give the desired results. (If coatings of different resistances are used in series, the higher the resistance the greater the distance at which it should be from the iron.) The resistivities of these materials will be much greater than those on the internal sheaths. Hence, the voltage drop and resistance along the inner sheaths may be neglected in the calculations.

If the resistance per unit length on the outside surface is a particular constant value in each of the zones directly above one of the inner sheaths, the problem is comparable to that of several cables connected in series, in which the resistance and capacitance per unit of length is to be considered, but in which the inductance is negligible at normal frequencies. Calculations have been made on this basis.

To indicate about what values of resistance to use on the outside surface, the following more simple method of calculation has been employed, although it has the disadvantage of involving slightly decreasing resistances as the distance from the iron increases. The resistivity was so chosen that the resistance and capacitance per unit of length were in a fixed ratio, as shown in figure 12*a*. The equivalent electric circuit was drawn as shown in figure 12*b*, where the resistivity and capacity per inch of length are all put in terms of those of the left-hand section of figure 12*a*. The voltages may be divided into 3 components as shown in figure 12*c*, and the equivalent circuits for each component are shown in the right half of figure 12*c*. Component 1 is applied on an open end line. Component 2 must be divided into 2 parts such that $E_s' + E_s'' = E$ and $I_s' = I_s''$, where all values are vector quantities. It is seen

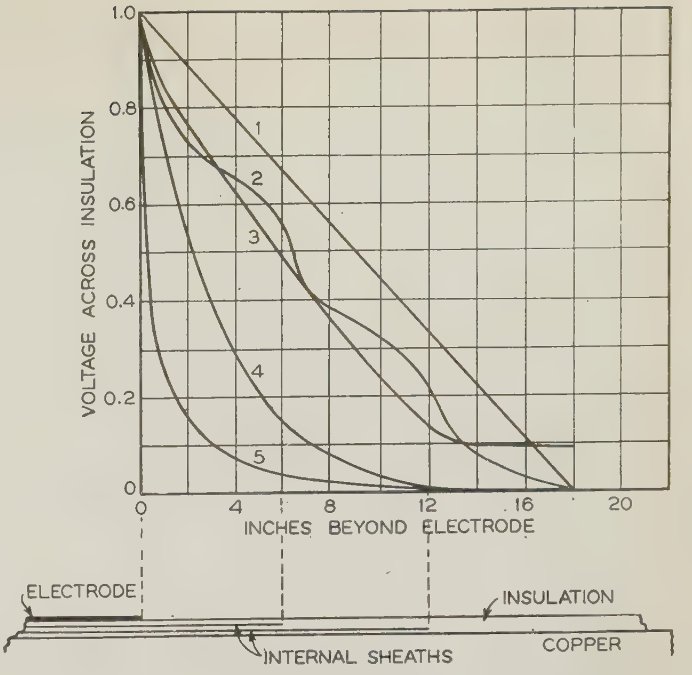


Fig. 13. Calculated voltage distributions beyond end of slot, for different combinations of internal sheaths and external resistances

1—Desired voltage distribution
2—Voltage distribution with internal sheaths only
3—Voltage distribution with internal sheaths and external resistances proportional to the capacitance from outside surface to sheath
4—Voltage distribution with a particular value of external resistance only
5—Distribution with no protection against corona

then that E_s' acts on a grounded end line and E_s'' on an open end line. Component 3 is treated in a manner similar to that used for component 2. The reals and imaginaries of each component are added to obtain the final distribution of voltage magnitudes and relative power factor angles. The resulting distribution is shown in figure 13 for comparison with the previously obtained data. The details of the calculation of these component voltages are omitted because the calculation is lengthy and because well-known methods are employed.[1]

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Design and Operation of Huntley Station No. 2

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Design and operation of the Charles R. Huntley station No. 2 in Buffalo, N. Y., largest 60-cycle steam-electric generating station on the Niagara-Hudson System, are discussed in this paper. As the plant and its associated electric energy delivery system replaced rather than supplemented an existing system, the basic design problems of the plant could be solved in a manner entirely consistent with the modern state of the art. Outstanding features of the plant are its split bus system, compact and flexible electrical layout, all-electrical auxiliary drives supplied at a single voltage, slag tap furnaces, and automatic furnace lighters; no coal is stored in the station building. Excellent results have been obtained by direct firing with pulverized coal and good over-all economy has been achieved under adverse load conditions.

BUFFALO'S first electric lighting was supplied by d-c series arcs in 1881. This was followed by 110/220 volt d-c Edison lighting and 125-cycle single-phase a-c lighting. In November 1896 Niagara Falls power was transmitted to Buffalo at 11,000 volts, 3 phase, 25 cycles. By 1898 motor generator sets were being installed to supply the existing d-c lighting, and frequency changers to supply $62^1/_2$ cycle a-c lighting. The 3 existing steam plants with belted generators then were scrapped, and Buffalo, for 18 years, depended entirely on transmitted Niagara Falls power.

Power for lighting the Pan-American Fair, in 1901, was supplied at 25 cycles. For several years the load on the frequency changer sets was kept constant by taking the growth in lighting load on the 25 cycle system. This resulted in changing large sections of Buffalo from $62^1/_2$ cycles to 25 cycles. From then until 1930, both of the a-c systems and the Edison d-c system grew side by side. In 1916 the 25 cycle Huntley steam plant of the Buffalo General Electric Company (now a subsidiary of the Niagara-Hudson System) was built and put in service in October of that year. It is situated in the town of Tonawanda, on the east branch of the Niagara River, $1^1/_4$ miles from the northwest corner of Buffalo. It is connected with the hydroelectric generating plants at Niagara Falls by 2 66 kv transmission lines, each 10 miles long.

Rapid development of the electric light industry was responsible for the simultaneous presence of these 3 systems of lighting in Buffalo. The development of satisfactory equipment for 60-cycle low-voltage network systems made conditions favorable for the adoption of a common 60 cycle system for all classes of service. The formation of the Niagara-Hudson Power System with its transmission ties to the 60 cycle steam and hydroelectric generating stations in the central and eastern parts of the state, and its proposed tie with the large 60 cycle generating plants in New York City, furnished additional justification for the decision to launch the 60 cycle change-over in Buffalo. The major items of this program consisted of building a 60 cycle steam plant, installing 3 large variable-ratio frequency-changer sets between the 60 and 25 cycle systems, and building a complete new 60 cycle delivery system to serve a population of 700,000 people in the metropolitan area of Buffalo.

Selection of the Site

In August 1929, engineers of the Buffalo General Electric Company were authorized to design and erect, under the supervision of N. R. Gibson, vice president in charge of engineering for the Niagara-Hudson System, a 60 cycle steam plant for Buffalo and the western division of the system. Several sites were considered for comparison with the existing 25 cycle station location. Those on Lake Erie, to the south and west of Buffalo, were eliminated because of higher cost. They required breakwalls to protect the circulating water intakes, more subtransmission to the load areas of Buffalo and the Tonawandas, and more transmission to the trunk lines to the east. Two sites to the north of Buffalo, on Ellicott Creek, were considered. One was eliminated because of the poor and limited amount of condensing water, and the other because of the longer subtransmission lines. Therefore it was decided to build the new 60 cycle station, known as Huntley station No. 2, just north of the 25 cycle station. The advantages of this site may be listed as follows:

1. It had an abundance of fresh relatively clean water for condensing purposes.
2. The load areas of Buffalo and the Tonawandas could be supplied directly from the plant by subtransmission circuits.
3. Coal receiving and handling equipment could be used jointly by both plants.

A paper recommended for publication by the A.I.E.E. committee on power generation, and scheduled for discussion at the A.I.E.E. summer convention, Ithaca, N. Y., June 24–28, 1935. Manuscript submitted March 19, 1935; released for publication April 8, 1935.

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4. Being adjacent to the 25 cycle plant, which has a capacity of 305,000 kw, would permit definite operating advantages, among which were: (a) joint supervision; (b) interchange of operating personnel to meet emergency conditions; and (c) joint use of machine shop, storeroom, first aid, and other miscellaneous facilities.

The relative locations of the steam plant, load areas, and transmission lines are shown in figure 1.

Design Requirements

In working out its design, the engineers considered that the station must meet the following requirements:

1. It must have rapid response to sudden changes in load. This need required a simple steam cycle and careful arrangement of controls.

2. Its reliability must be of the highest order. This requirement emphasized the need of rugged equipment with the possibility of some sacrifice in efficiency.

3. It must carry its full capacity continuously for months at a time, occasioned either by a low rate of water flow at the hydroelectric plants, or by large hydroelectric units being out of service for repairs.

4. The installation cost per kilowatt of capacity must be low as it was estimated that the capacity factor would not exceed 25 per cent for the life of the plant, although a combination of circumstances might produce an occasional annual capacity factor of approximately 50 per cent.

5. Operating and maintenance costs must be low for the same reason as given in item 4.

6. It must supply an expected load of 100,000 kw in the Buffalo area, and, in addition, supply energy to or receive energy from the Niagara-Hudson bulk power system.

7. Being part of a large bulk power system, the annual peak load of which already had exceeded 1,000,000 kw, would justify relatively large units.

8. Initial electrical ties would consist of: 21 22-kv 10,000-kva subtransmission feeders to the local load areas; 2 110-kv 60,000-kva transmission lines to the bulk power system; and 1 22-kv 25,000-kva frequency changer set.

9. The design of the station buildings must be such as to offer as little restriction as possible to the choice of equipment for future extensions.

The very fact that the designs of the steam station and the delivery system were not handicapped by the problem of having to fit into an existing system placed squarely upon the engineers the responsibility of selecting the best possible system consistent with the economics of the problem and the state of the art. How well this was accomplished is demonstrated by the fact that in the $4^1/_2$ years since the system was completed there has not been a single interruption to the low voltage network service or loss of voltage on the 22 kv bus of the generating station. On 2 occasions service was interrupted to the 60 cycle automatic substations because of faulty relay settings, both occuring within the first few months of operation.

Main Building

Figure 2 shows a cross section of Huntley station No. 2, from the coal pile to the outgoing transmission lines. A railroad track extends through the south end of the boiler and turbine rooms where hoists or the turbine room crane may lift machinery directly from the cars. The crane has a 100 foot span and a capacity of 150 tons. Monorails with trolley hoists are provided over the boiler feed pumps and mills. A motor operated crane in the central bay of the top floor of the boiler house is used as a means of transferring a $7^1/_2$ ton electric hoist with its load to the various monorails over the forced and induced draft fans and air preheaters.

The 5,213,000 cubic feet inside volume of the main buildings of Huntley station No. 2, costing 36.5 cents per cubic foot, is distributed as follows:

	1,000 Cubic Feet	Cubic Feet per Kilowatt
Administration building	108	0.7
Electric bay and control room	600	3.7
Turbine bay	1,500	9.4
Boiler bay	2,700	16.9
Coal machinery room	305	1.0
Totals	5,213	32.6

The steel frame of the building and the turbine foundations are supported on steel caissons extending 40 feet to rock. They vary from 48 inches to 89 inches in diameter and are filled with reinforced concrete. The turbine and building caissons are tied together by reinforced concrete beams poured integral with the concrete floor, which is 12 inches thick. The main operating floor is 32 feet above the basement floor. In this distance the turbine foundations are built of reinforced concrete and are independent of the building steel. The transformer and mill foundations are supported by concrete piles

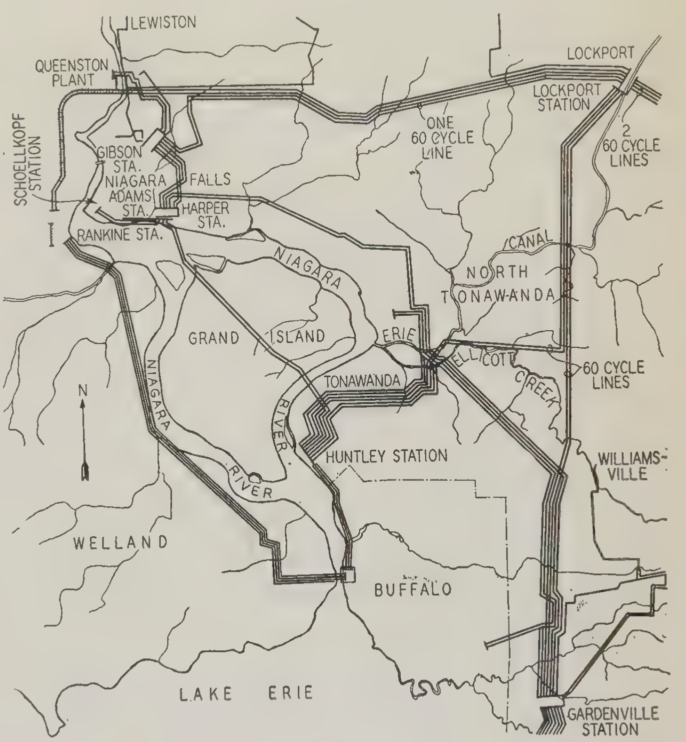


Fig. 1. Relative locations of steam plant, load areas, and transmission lines

poured in place. The coal bunker is supported on a continuous spread footing.

Turbogenerators

To meet the design conditions, 2 single spindle, turbogenerator units without direct connected exciters were selected, each rated 80,000 kw, 100,000 kva, 1800 rpm, 12,000 volts. A tandem unit of the same capacity would have given better efficiency, but the increased cost was not justified for so low a capacity factor. The building to contain these units, with their boilers and accessories, was designed so that units of 200,000 kva, tandem type, could be installed crosswise of the station if found to be desirable for future extensions. Figure 3 shows a view of the turbine room; note the turbine panels mounted in the wall. Rapid response to sudden changes in station loading (design requirement 1) often requires quick starting of the turbines. To facilitate this, the units were equipped with motor operated turning devices which will rotate the turbines at 1 rpm during idle but available periods. This device has reduced the normal time required to start from 90 minutes to 45 minutes; in an emergency, the units can be brought up to speed in 25 minutes. After trying several loading cycles, such as increasing the load 10,000 kw every 10 minutes, it was decided to determine how quickly a turbine that had been carrying 5,000 kw for an appreciable time could pick up load. Accordingly a test was made by increasing the load on one machine from 5,000 to 85,000 kw and simultaneously decreasing the load on the other machine by the same amount. This transfer of load was accomplished in 33 seconds without any evidence of undue strain on either machine.

Table I shows how the individual turbines have operated since the plant was started. Note the long hours of operation when the turbine loadings have been less than 7 per cent of their rated capacity. The annual capacity factors of the individual turbine units have varied from 6.4 to 34.7 per cent, whereas the station net annual capacity factor has varied from 5.7 to 25.8 per cent in the 4 years of operation.

Steam Generation

The use of one boiler per turbine was given serious consideration. Based upon experience at Huntley station, which showed that the availability factor of the boilers was less than that of the turbines, it was decided to install spare boiler capacity. Boilers at Huntley station are taken out of service once a year for insurance inspection and a general overhauling, whereas turbines are not taken out oftener than once in 2 or 3 years. National data[1] recently accumulated indicate an availability factor of 86.9 per cent for

1. For all numbered references see list at end of paper.

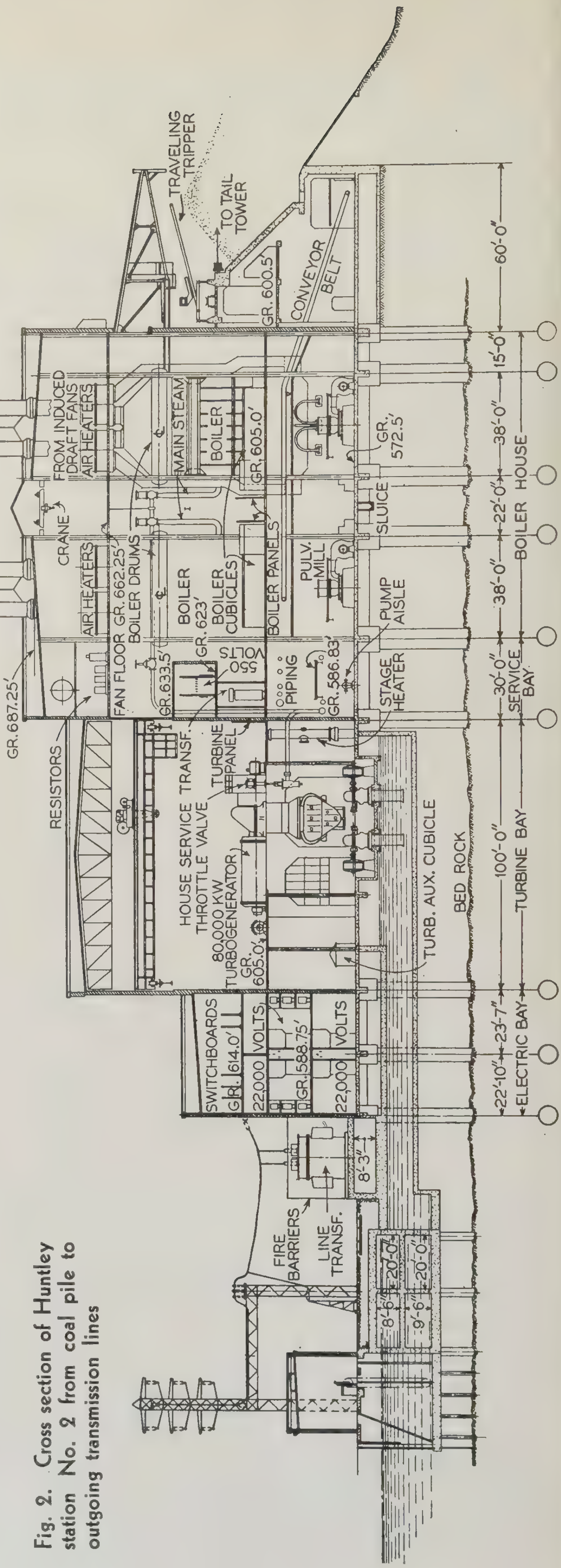


Fig. 2. Cross section of Huntley station No. 2 from coal pile to outgoing transmission lines

pulverized fuel fired steam generating units and 92.8 per cent for turbines. This is equivalent to an over-all availability factor for plants having one boiler per turbine of 80.7 per cent minimum (86.9 × 92.8) and 86.9 per cent maximum. Accordingly, 4 boilers were installed, each of such capacity that 3 boilers could deliver continuously the required 1,640,000 pounds of steam per hour throttle flow required for 160,000 kw net station output. The fourth boiler, although regarded as a spare unit, would be of material assistance in picking up loads quickly during stand-by periods, and in addition would operate normally with the other 3 boilers for loads in excess of 120,000 kw.

Each boiler is 60 sections wide and 22 tubes high, and has 36,792 square feet of heating surface and a 9,350-square foot interdeck multiple-loop superheater. The 3,301 square feet of heating surface in the 4 furnace walls and the 900 square feet in the water cooled bottom surround a 22,900 cubic foot furnace designed for a heat release of 32,300 Btu per cubic foot at its rated capacity of 560,000 pounds of steam per hour.

The boiler units have operated continuously at 620,000 pounds per hour for a 3 hour period. The 4 lower rows of tubes in the boiler are double spaced, both vertically and horizontally, forming a slag screen to prevent the accumulation of slag on the main tube bank. The boilers and water walls each are supported independently at the bottom rather than hung in position.

Furnaces are of the slag tap design developed in Huntley station No. 1 in 1926 and 1927. The only limitation this design places on the purchase of coal is that the coal ash shall have a fusion temperature not to exceed 2,500 degrees Fahrenheit.

During long periods of operation of the plant at minimum load (5,000 kw), one boiler supplies the necessary 65,000 pounds of steam per hour. Two other boilers normally are held in hot reserve at a pressure not more than 100 pounds per square inch (gauge) below line pressure. A furnace that has been operating at this light load for days usually can be tapped within 2 hours after the loading has been increased to a rate of 120,000 pounds of steam per hour. It requires 4 tons of coal each 24 hours to keep one of the boilers within 100 pounds of line pressure.

Furnace Lighting Equipment

By means of special igniting oil burners the hazards and delays incident to hand lighting of powdered coal furnaces by torches have been eliminated. The oil is ignited automatically by an electric spark. A push button control station is mounted on the wing of each boiler panel as may be seen at the extreme left of figure 4. Within 3 seconds after the button is pushed 6 large oil flames are produced in the furnace, one in front of each of the 6 powdered coal burners, assuring effective ignition of the coal. During a 2 year period these lighters were used for approximately 6,000 boiler starts without causing a single puff. The lighters are withdrawn from the furnace, when the coal is well ignited, by pushing another button. The results obtained have been eminently satisfactory with but slight maintenance cost. The operating department considers the lighters one of the most valued features of the plant.

Method of Firing

The last stoker fired boiler was added to Huntley station No. 1 in 1924, and in 1925 additional boilers were purchased, equipped for direct firing of pulverized coal. This equipment operated so successfully that the decision was unanimous to use pulverized coal firing for the new plant. The direct fired system was justified as against the bin system of pulverized coal firing for the following reasons:

1. The installed cost was less.

2. The direct fired system had met successfully the exacting flexibility requirements in the 25 cycle plant.

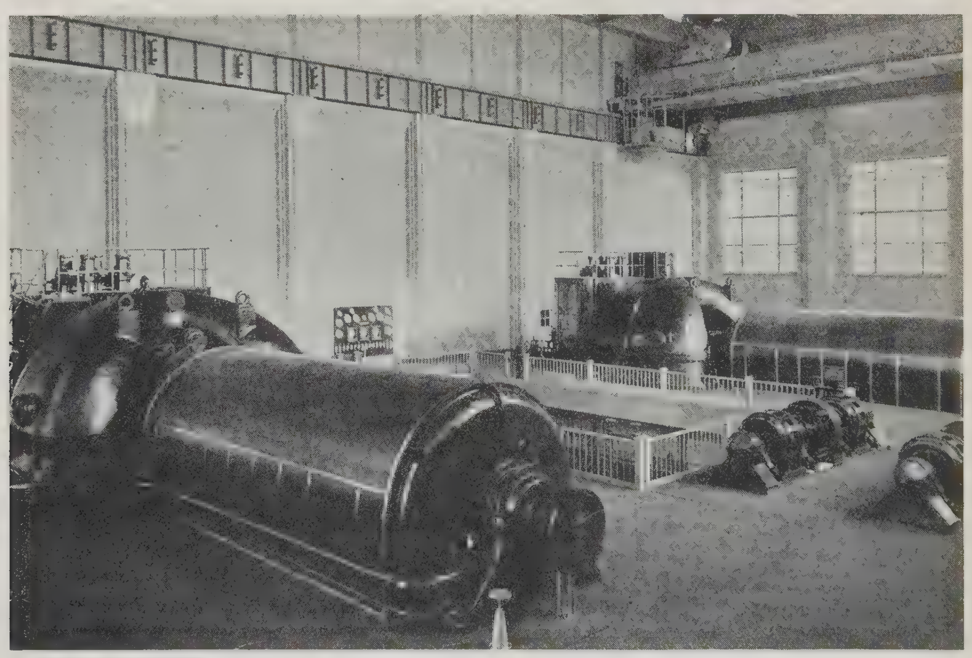


Fig. 3. Turbine room looking toward boiler room

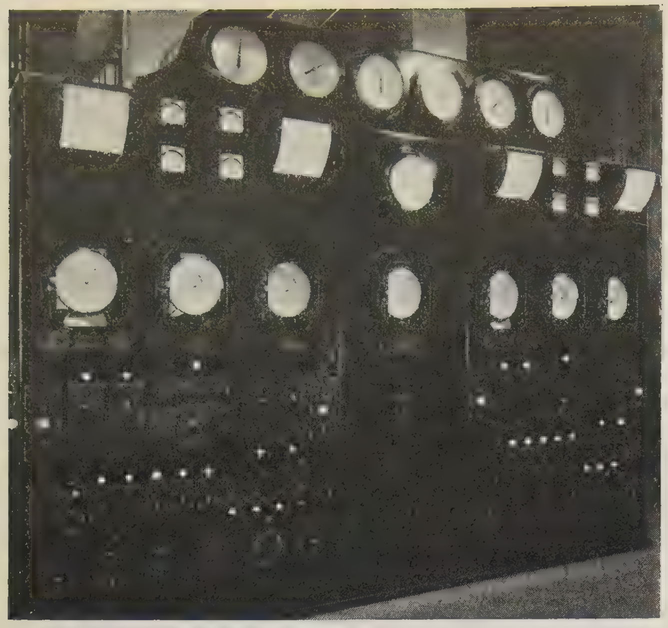


Fig. 4. Boiler control panels with master pressure controls on center panel

3. The hazards of bin fires and explosions when burning coals of high sulphur content were eliminated.

4. The nuisance resulting from the pulverized coal packing and caking in the bins were avoided.

5. No data could be found to prove that the direct fired system was less efficient or required more energy per ton of coal burned than did the bin system.

6. It was the opinion that the direct fired system could be made to have the same speed of response as the bin system.

Referring to the foregoing item 5, the efficiency of either system is made up of 2 parts: (1) the thermal efficiency of the fuel burning and heat recovery equipment, and (2) the mechanical efficiency of the pulverizing and transport equipment. For equal fineness of pulverization, the thermal efficiency should be the same for either system. Well designed efficient mixing burners are in use in both systems, and the method of preparation should make no differences. The bin system may use less energy for pulverization, but this will be offset by the additional energy used in transporting the pulverized fuel.

In further reference to the foregoing item 5, speed-of-response tests were conducted on one of Huntley No. 2 boilers, the results of which are shown in figure 5. During the tests with one mill in service, the steaming rate of the boiler was increased from 110,000 pounds to 320,000 pounds per hour in 2.7 minutes, or at the rate of change of 78,000 pounds of steam per hour per minute. Under this condition the control shut the feed water off entirely and the boiler water level rose $7^1/_2$ inches, thus demonstrating that in this station, where there are 2 mills per boiler, the limit to the rate at which the load can be picked up is set by the rise in boiler water level and not by the system of firing. The foregoing rate of pickup is equivalent to an increased station output of 7,800 kw per minute per mill.

As specified in design requirement 3, the plant must be able to carry full load continuously for long periods of time. It should be noted from figure 6 that on February 13 full load (160,000 kw) was carried for more than $15^1/_2$ hours. Full load also was carried for more than 12 hours on each of the 2 succeeding days. The load curve logs also illustrate the extreme variation in the station load.

Operating Procedure During Load Changes

Under normal operating conditions station load changes are made at the rate of 10,000 kw per minute. Load bulletins are provided in the turbine and boiler rooms which indicate the actual and anticipated load on the station. The actual-load hands of the load indicating instruments are positioned by means of a remote metering device, and the anticipating hands are positioned by the electrical operator in the control room through a selsyn sending and receiving device. Two horns, one in the boiler room and one in the turbine room, are sounded from the control room to announce a load change.

Thirty seconds after sounding the alarm for a load change, the electrical operator starts to change load at the rate of approximately 10,000 kw per minute. He does not hesitate to change load at this rate under normal conditions. However, if his steam gage shows the pressure to be less than 425 pounds and falling, he must change his procedure accordingly. Each turbine is provided with a load limit device to protect it against pulling water over from the boilers upon a sudden load increase resulting from a system disturbance. This device limits the load on the

Table I—Operating Record of the 2 80,000 Kw Generating Units Installed in Huntley Station No. 2

Year	Unit No.	Hours Operation at Various Loads (in Megawatts) 90	85	80	70	60	50	40	30	20	10	5	Hours Idle But Available	Hours Idle But Unavailable	Elapsed Time, Hours	No. Idle Periods	Unit Capacity Factor	Net Station Capacity Factor
1930	1	0	0	1	3	18	150	587	858	1,259	1,585	1,685	138	49	1,872*	9	32.8	——
1931	1	0	0	1	3	5	178	520	965	1,506	3,000	4,593	2,517	1,650	8,760	28	10.6	8.1
	2	0	0	2	3	18	41	126	306	546	1,451	3,121	2,182	298	5,601†	86	7.7	
1932	1	0	1.5	2	3	4	6	8	12	56	2,612	5,125	1,333	2,326	8,784	30	6.4	5.7
	2	9	14	54	67	123	150	248	385	470	2,154	3,837	239	3,741	8,784	41	7.0	
1933	1	18	72	266	770	1,544	2,362	3,013	3,472	3,947	6,795	8,396	1,206	125	8,760	26	34.7	25.8
	2	0	16	183	603	1,085	1,692	2,190	2,462	2,610	2,824	2,864	1,733	4,163	8,760	77	20.5	
1934	1	2	47	197	418	786	1,240	1,805	2,348	2,836	4,250	5,050	1,640	2,070	8,760	42	22.1	22.5
	2	1	41	198	418	868	1,421	2,185	2,812	3,461	4,882	5,869	2,600	291	8,760	83	26.1	

* Unit No. 1 started October 15, 1930. † Unit No. 2 started May 12, 1931.

turbine by means of an adjustable stop for the travel of the governor beam. The position of this limit is controlled from the control room by the electrical operator. The setting of these devices limits the increase in load to 12,500 kw for each active boiler. Immediately following the initial disturbance, the operator may raise the load limit and allow the machines to pick up more load, if needed, at a rate not to exceed 10,000 kw per minute per active boiler.

Air Heaters

There are 2 45,000-square foot regenerative air heaters per boiler. In selecting this type of heater a leakage factor of 10 per cent was allowed. To take care of possible corrosion troubles, the top or cold end of the 42 inch long heater section was made so that it could be replaced easily with corrosion-resistant steel. During 1932 the boilers operated for more than half of their active hours at outputs less than 70,000 pounds of steam per hour, and to date no corrosion can be detected in the air heaters.

A test was made that appears to explain the absence of corrosion. Fly ash was collected from the flues leaving the heaters, the collecting receptacle being arranged to cool the gases to various temperatures. The samples of fly ash so collected were mixed thoroughly with a measured quantity of distilled water and allowed to stand for a few hours. The water then was filtered off and its pH value (hydrogen ion concentration) determined. This water was strongly alkaline when the fly ash was collected at the temperature of the gases leaving the heater. As the temperature was lowered the alkalinity became less pronounced, but it was still alkaline at a temperature 100 degrees below the dew point of the flue gases calculated, taking account of sulphur content.[2] From this it was concluded that:

1. Pulverized fuel fly ash is strongly alkaline when it leaves the flue gases at temperatures above the dew point for the gases.

2. Pulverized fuel fly ash has a strong tendency to absorb acid moisture. This tendency enables it to carry off mechanically appreciable quantities of moisture, preventing it from depositing on metal parts and corroding them.

3. The temperature of the pulverized fly ash and flue gas may be reduced considerably below the dew point for the flue gas before its reaction becomes acid.

Draft System

Air and flue gas passes for the boilers are designed so as to keep down the friction in the system. Vanes are used in elbows where possible and streamlined enclosures are used around pipes passing through the air duct. Figure 7 shows how the forced draft air ducts are tied together at the discharge from the fans and again by a ring duct at the burners. The gas passages also are tied together on both sides of the induced draft fans; this permits operating the boilers at 70 per cent capacity with only one set of fans. The preheated air delivered to the primary air fans under pressure from the forced draft fans is tempered by a damper-controlled by-pass around the air heater. At full load on the boilers the flue gases leave the air heaters at 280 degrees Fahrenheit, and the secondary air enters the furnace at 600 degrees Fahrenheit.

Coal Handling

There are 2 methods of receiving coal. A rotating 100-ton car dumper with integral track scales was provided for rail delivery of coal, and a boat unloader with a capacity of 10,000 tons in 20 hours for the delivery of water-borne coal. From the car

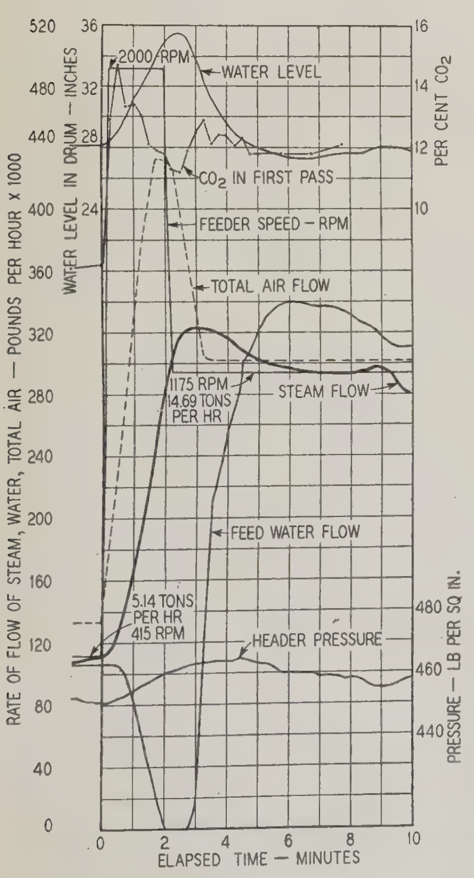


Fig. 5. Speed of boiler response with one pulverizing mill operating

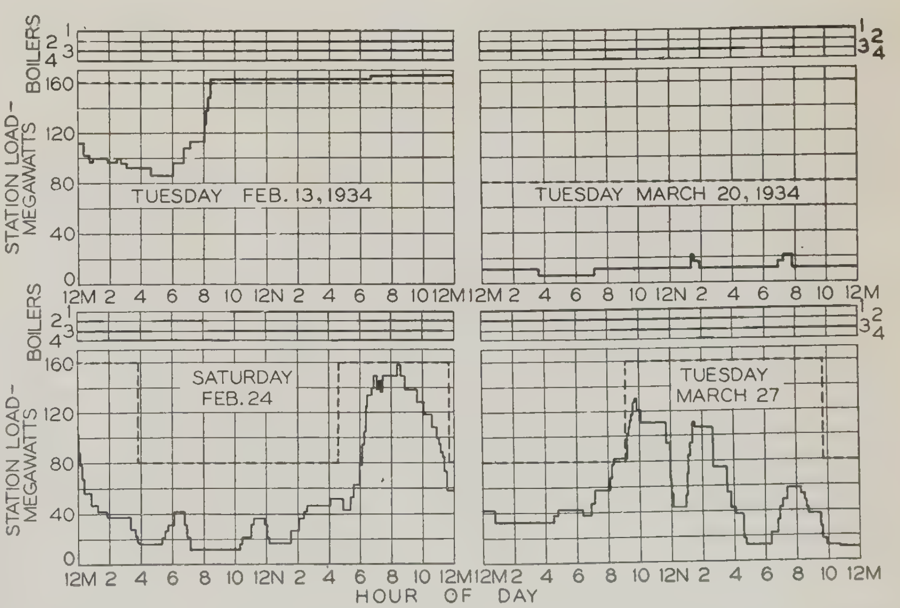


Fig. 6. Load curves for 4 typical days, showing boilers in service and total station load; dashed lines show rated capacity of turbines operating

dumper and dock, main belt conveyors of 750 tons per hour capacity (1,500 tons future) carry the coal to a balancing bin and thence to 2 rotating cylinder type breakers for the removal of foreign matter and the crushing of mine run coal to $1^1/_4$ inch size, thence over a magnetic separator to the storage piles.

Storage of coal at Huntley No. 2 is unique in that no raw or pulverized coal is stored inside the plant. The outside bunker is combined with the storage yard. Crushed coal is stored or reclaimed by a drag line scraper which operates between a movable head post and a movable tail car, both of which are operated electrically from a control cab.

Coal for the house enters through 8 48 inch square openings under the powerhouse end of the pile and through combined roll crushers and feeders to 18 inch belts which supply the individual mills. Each conveyor is started and stopped automatically by the automatic scales which weigh the coal in 400 pound lots, the number of starts being controlled by the rate of coal consumption.

The main conveyors are driven by high torque motors suitably protected from coal dust. These motors are started at reduced voltage in order to take up the slack in the drives and belts, and then are accelerated at full voltage. All motor starters, with accessory equipment, are grouped conveniently into "cubicles" and located in rooms especially constructed for them. A dust-tight push-button station is located at each motor for starting, and a "stop" button is provided for approximately each 100 feet of conveyor length. The usual interlocking is provided to prevent starting a conveyor out of sequence; and if a conveyor stops, all belts supplying it will stop.

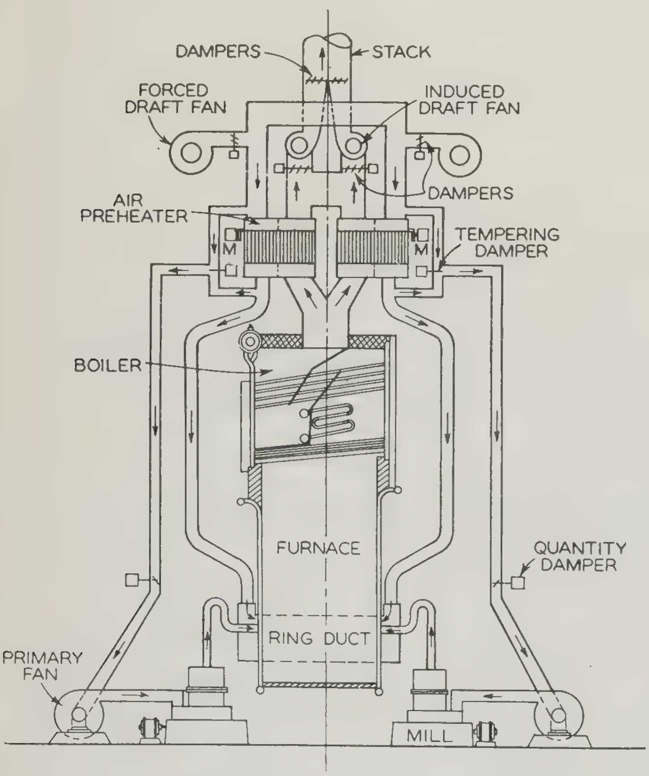


Fig. 7. Draft system for 560,000 pound per hour boiler

Heat Balance

The heat balance diagram for one of the 80,000 kw turbines is shown in figure 8. The 17 stage turbine is bled at the sixth, eighth, eleventh, and fourteenth stages, for supplying steam to the feedwater heaters and evaporators. The evaporator equipment, which may be operated in either single or double effect, is floated on the system. The hot well pumps force the condensate through the 2 low pressure heaters and the evaporator condenser to the boiler feed pump suction header. These pumps force the condensate through the eighth and sixth stage heaters to the boilers under the control of 3-element feedwater regulators. The low pressure heaters can be by-passed as a unit, likewise the high pressure heaters. Push buttons to start and stop, and control the speed of the boiler feed pumps are mounted on the boiler panels together with the necessary indicating flow meters.

In conformity with the fundamental scheme for the essential auxiliaries, as described under the heading "Auxiliary Power," 2 boiler feed pumps are provided for each turbine unit, that is, one per boiler with a fifth pump as a spare unit. The fifth pump may draw water from the condensate header of either unit and feed into either boiler feed header. When a pump is not out of service for repairs both inlet and outlet valves are kept open so as to permit full control from the boiler room panel, the boiler feed pressure being held by check valves.

The saving of the heat from the generator air and lubricating oil coolers did not prove to be justified at the low capacity factor expected.

Condensers and Cooling Water

Each 45,000-square foot single-pass condenser is bolted solidly to the turbine casing with part of its weight supported by springs. Steam jet air removal is used. Each of the 2 circulating water pumps is driven by 2-speed squirrel cage motors. When both pumps are operating at full speed, 80,000 gallons of water per minute is supplied to the condenser. A horizontally divided water box permits cleaning when operating at partial loads.

The location of an existing 305,000 kw plant upstream, with its circulating water discharged to the river where the intakes for the new plant would be located, necessitated a major undertaking of tunnel construction. The main tunnels are designed to handle a million gallons of water per minute.

The raw water cooling and general utility systems are designed for 3 separate pressure levels, so as to reduce losses when the requirements are more or less continuous:

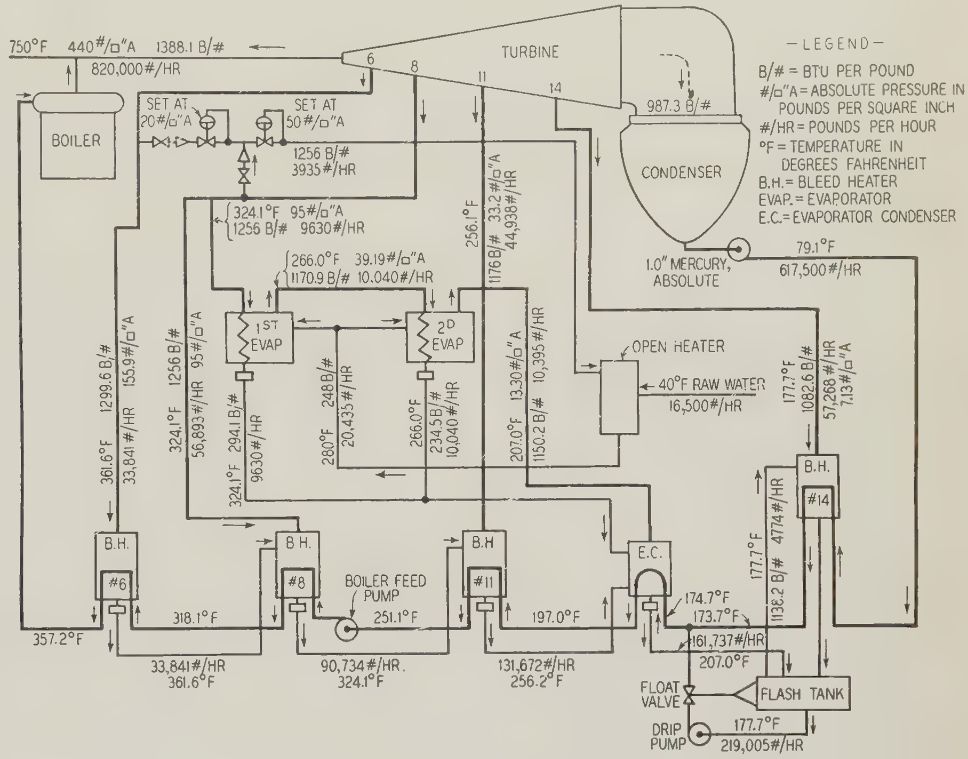
1. The low service system at 20 pounds pressure provides cooling water for main transformers, generator air coolers, and turbine oil coolers.

2. The house service system at 65 pounds pressure supplies water for cooling the house service transformers and evaporators, and for general utility use around the plant.

3. The slag sluicing at 175 pounds serves for ash removal and boiler washing, also for the hydro-jet vacuum cleaning system.

One pump normally pumps all slag sluicing water. The same is true of the house service system. There is a third pump, however, which is duplicate of the slag sluicing pump and is driven by a 2 speed motor, permitting its use as a spare unit on either the house service or slag sluicing systems. Further interconnection between the 2 systems is provided through check and reducing valves to keep house service pressure on the slag sluicing lines at all times and for other emergencies. An elevated tank "floats" on the house service system. The low service is fed by a pump at each unit and a third as a spare pump. The importance of this service required interconnection through a reducing valve with the house service.

Fig. 8. Heat balance diagram for 80,000-kw 17-stage turbine



Choice of Voltage

The station was built primarily to supply the distribution system of the metropolitan area of Buffalo. A thorough study of the economics of the problem indicated that the delivery of the energy should be at 22 kv by means of subtransmission underground feeders directly to the load areas. Ten years of experience in Buffalo with a similar 25 cycle subtransmission system of the same voltage had proved its reliability. To have transformed a portion of the energy for transmission, either overhead or underground, to a receiving station or stations in remote parts of the city with subtransmission circuits from these stations to the load areas, would have been far more costly and probably less reliable. A voltage of 22 kv was also suitable to supply large power consumers almost anywhere in the metropolitan area.

After giving consideration to experience in the 25 cycle station with a combination of a 12 kv generator and an autotransformer for obtaining 22 kv at the station bus, and after a careful study of the economics of the problem, it was decided that this method would give a greater degree of reliability than would a generator wound for 22 kv, with no increase in cost or sacrifice in efficiency. In addition the autotransformer could be designed to provide distinct operating advantages as explained in succeeding paragraphs.

Electrical Connections

The scheme of electrical connections is known as the "split bus scheme." This scheme was evolved during the expansion of the 25 cycle system. It requires that each large transformer connected to the bus have the equivalent of 2 22 kv windings normally connected to opposite busses.[3] This gives a low through reactance between a generator or line to the busses, but a high transfer reactance between busses. For example, on the generator autotransformer the through reactance from generator to both busses is 5.46 per cent, but the transfer reactance between busses is 50.4 per cent. This design is very effective in limiting short-circuit current without excessive reactance to the load, it eliminates the use of large reactors in the busses, and provides highly satisfactory stability between machines because a comparatively high voltage is maintained on the "good" bus (actually the voltage tends to rise) during fault conditions on the other bus. Transformers for the outgoing lines and the frequency changer are also of the split winding type.

With all the equipment in service, including the 2

80,000 kw generators, 2 60,000 kva transformers from the 110 kv system, and the 20,000 kw frequency changer, the short-circuit value on one of the 22 kv busses is approximately 640,000 kva. If the station were extended to include 6 80,000 kw generators and 6 60,000 kva transformers, the short-circuit value could be held to 715,000 kva by sectionalizing the 22 kv busses and utilizing the split windings of the transformers for tying the bus sections together. From the connection diagram, figure 9, it should be observed that the various bus sections are tied together also through the subtransmission circuits and the substation and network transformers, which also contributes to a unified and stable system. The reactors in the outgoing feeder circuits are required to limit the short-circuit duty on the substation breakers.

All neutrals of the generators, autotransformers, line transformers, and frequency changer, when in service, are connected normally to a neutral bus and then grounded through a 5 ohm resistor. By having all neutrals connected to a common bus, a continuous system ground is assured should one or more machines be tripped out. This arrangement permits effective relaying without excessive residual current. There is no measurable exchange of harmonic current between the neutrals of the machines.

Switching Equipment

A thorough study of the types of switching equipment available led to the selection of simple and rugged equipment of the conventional type installed indoors. Vertical isolated-phase equipment, oil-filled vertical-lift switches with horizontal draw-out, and other related types of equipment were investigated, but were discarded either because of high cost or maintenance difficulties. It is the writer's opinion that conventional type switching equipment of improved design often is not evaluated properly, particularly when comparing it with the more unconventional types. In other words, conventional type switching equipment may incorporate all the improvements actually required over similar equipment of earlier design.

The circuit breakers were built at the factory in steel frames, suitably enclosed, and shipped and installed as a unit, the field work consisting only of bolting to the floor. The circuit breakers have an interrupting capacity in excess of the estimated

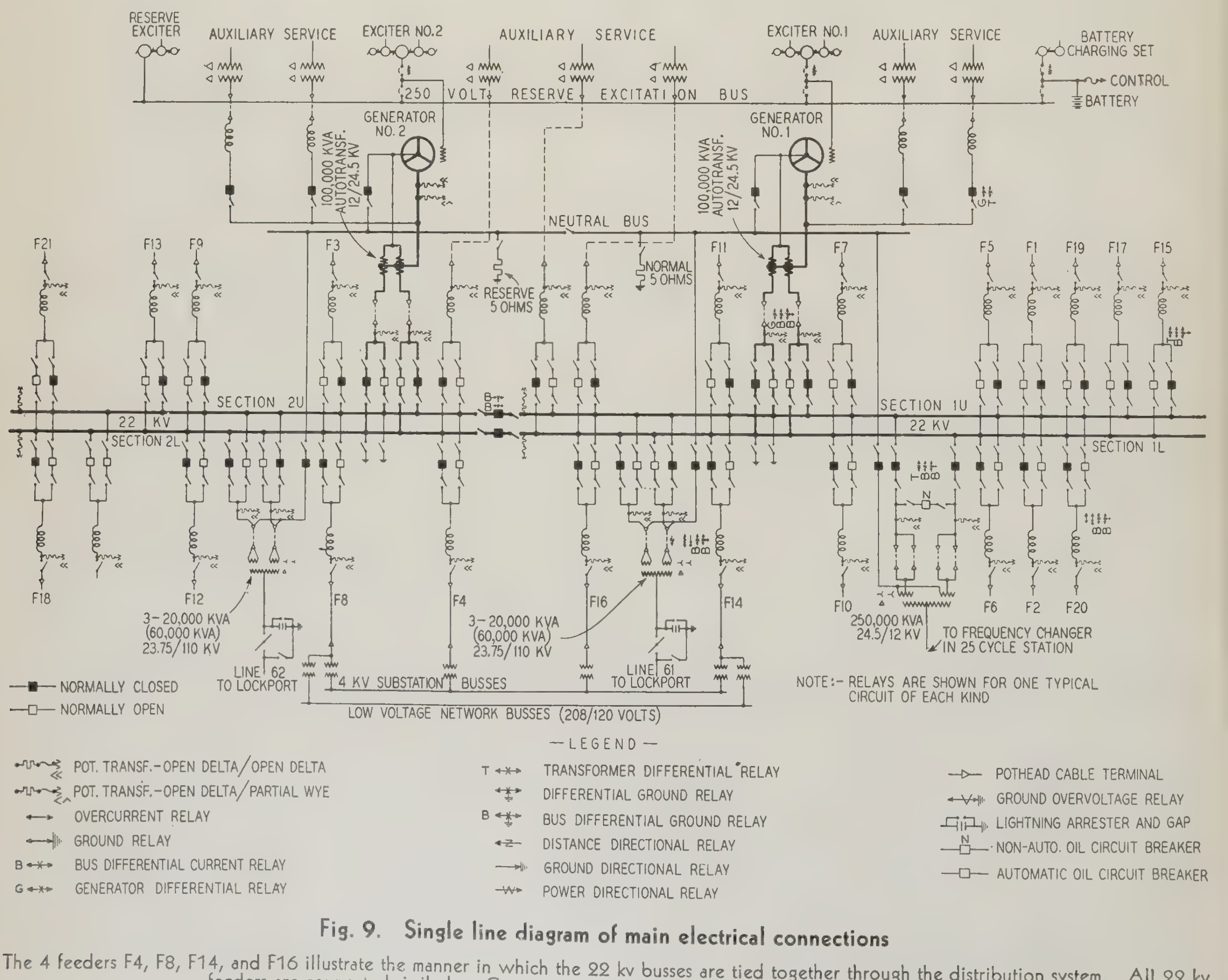


Fig. 9. Single line diagram of main electrical connections

The 4 feeders F4, F8, F14, and F16 illustrate the manner in which the 22 kv busses are tied together through the distribution system. All 22 kv feeders are connected similarly. Connections at the distribution systems are simplified for clarity

maximum requirements under normal operation. This margin was considered necessary to meet unexpected future requirements and to provide safe operation under abnormal conditions. Outgoing and auxiliary feeder breakers have a specified interrupting capacity (OCO plus OCO basis) of 1,000,000 kva, and the generator and transformer bank breakers 1,500,000 kva. The disconnecting switches are stick-operated and are mounted on strong supports inside steel and molded composition compartments; they have flashover voltages (110 kv dry) and creeping distances considerably in excess of ordinary standards. Dry type current transformers of the stud or through type, with suitable ground shields between the primary and secondary windings, are used.

The main busses and generator interconnections consist of rectangular copper bars with each phase divided into 2 parts, each part separately insulated for full voltage, and the 2 parts mounted on common insulated porcelain supports. Interconnections for the remainder of the circuits are insulated similarly. This method of phase protection is absolutely gas tight and need not be completely inclosed in compartments, the only protection required being reasonable isolation between adjacent circuits. The floors are suitably isolated from each other to prevent communication of trouble as are also the aisles on each floor.

Arrangement of Switch Bay

The switch bay (see figure 10) was constructed with flush wall spaces with no projecting columns, and with the bottoms of the ceiling beams all at the same level. This simplified the design and facilitated the work, there being no obstructions to interfere. The switching equipment occupies the first and second floors, and the neutral ground resistor switches, control battery, electric shop, control conduit terminals, etc., were placed on the third floor. It may be noted that the busses are located between, and inclosed by, 2 concrete bearing walls. The circuit breakers are bolted to the floor with their isolating disconnecting switches located directly above them. The door in the front of the disconnecting switch compartment is interlocked with the breaker mechanism. It is apparent from the diagram that 3 breakers, instead of 4, could have been used on the generators and transformer banks. However, 4 breakers simplified the layout and cost less than 3 breakers because of their lower current carrying capacity and, in addition, materially contributed to the flexibility of switching and security of operation. The potential transformers and fuses are housed in metal cells, and the feeder reactors in concrete cells.

An interesting feature is the use of 3-phase lead-covered cables on the 22 kv side of the generator autotransformers and 4-conductor single-phase cables for the line transformers. As may be noted from the wiring diagram the neutral of the line transformers is formed at the yoke end of the 4 conductor cables, which eliminated sheath voltage. These cables terminate in an oil-filled terminal chamber

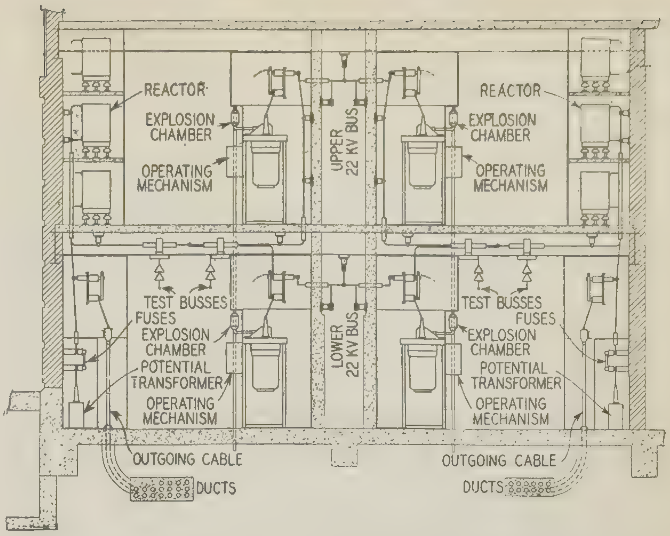


Fig. 10. Cross section of switch bay at 22 kv feeder equipment

equipped with a conservator at the transformer end, and in a similar manner in an oil-filled terminal chamber equipped with a pressure reservoir at the opposite end. The cables are wiped to plain brass sleeves to allow the oil in the terminal chamber to enter or leave the cables freely, thus assuring continuous oil saturation of the cable insulation with but little likelihood of the formation of voids. All remaining 11-kv and 22-kv 3-phase cables used in the station terminate in a similar manner, with the same degree of protection. Where required, the lead sheaths are armored with copper tape to withstand internal pressure which may be caused by a high oil head or by expansion of the oil during a heating cycle.

A forced ventilating system is provided which will cause air to flow from the outside into the electric bay and discharge it into the turbine room in the summer; in the winter it will cause heated air to flow from the turbine room into the bay and discharge it into the cable and piping tunnel under the transformers, where the heated air will prevent freezing of the water piping. The direction of air flow may be changed at will. Accumulation of smoke and gas will be dissipated quickly by the ventilating system.

Connections to Bulk Power System

Huntley station No. 2 is tied into the Niagara-Hudson bulk power system at Lockport, N. Y., through the 60,000 kva transformer banks, which have voltage ratio control, and the 110 kv transmission lines. The bulk power system extends across the State of New York and comprises the generating and transmission systems of the constituent operating companies. Through the bulk power system, interconnection is maintained with the power systems of New England and New York City—in fact, the Hell Gate steam station in New York City usually regulates the frequency of the system.

The bulk power system also is tied into the 25 cycle system through 3 variable-ratio frequency-changer sets, of which there are 2 of 18,000 kw capacity at

Lockport, and 1 of 20,000 kw capacity in Huntley station No. 1 at Buffalo.

Fault Protection

In order to secure protection for phase-to-ground faults on the 22 kv system a 5 ohm resistor was connected between the neutral of the system and ground, which permits only sufficient current to flow for effective relaying. A few years ago, when there were a considerable number of cable faults, the neutral was solidly grounded temporarily in order to reduce the stress on the insulation of the unfaulted phases, with the expectation that the number of faults could be reduced. The results were rather surprising; when a fault did occur in one of the underground cables it would clear itself so quickly (less than 3 cycles) that the instantaneous residual relays did not have time to operate, nor was it known that a fault actually had occurred. In several instances the cable inspectors entered a manhole to find an exposed live 22 kv conductor with fortunately no serious results. After a very short time the neutral again was grounded through the 5 ohm resistor.

In general, percentage differential relays are used in which the load current exerts an opening torque, allowing very sensitive settings. A generator with its autotransformer are protected as a unit; if a relay contacts it will trip the main circuit breakers, field breaker, neutral breaker, and throttle, and also initiate a transfer of the auxiliary motors as explained under heading "Auxiliary Power Equipment." Should mechanical trouble develop on a turbogenerator, the throttle will be tripped manually, which in turn trips the main circuit breakers, but the field breaker will remain closed in order to bring the unit to a quick stop.

A set of differential relays protects each bus section. These will trip all of the circuit breakers connected to the faulted section. On 2 occasions these relays have acted to clear a fault; once when the removal of a protective ground was overlooked; and once when a disconnecting switch was opened under load (before the interlocks were in use), causing a flashover to ground. Each time the relays functioned efficiently with a minimum of damage and without loss of any load or of stability.

Each of the house service transformer banks is equipped with a set of differential relays of the autotransformer type.

The 2 outgoing 110 kv lines with their transformer banks when operating singly are protected by distance impedance relays, in which the voltage drop through the transformer bank is compensated. When operating in parallel, instantaneous current

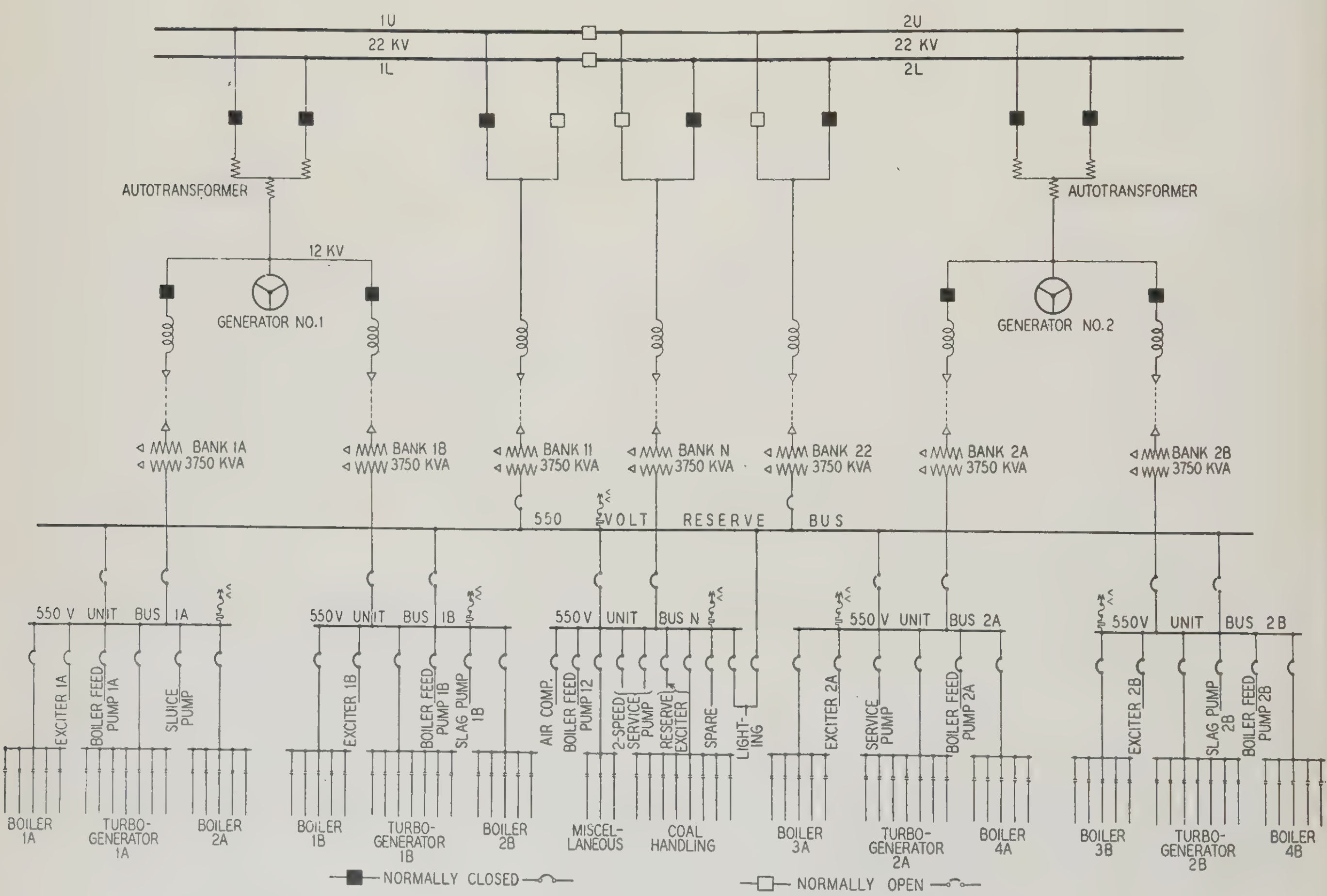


Fig. 11. Single line diagram of electrical connections for auxiliary power

Each group of boiler auxiliaries consists of: induced draft fan, forced draft fan, pulverizing mill, primary air fan, and miscellaneous units. Each group of turbogenerator auxiliaries consists of: a 2-speed circulating-water pump, 2 cooling fans, hot well pump, drip pump, and turbine turning motor. Coal handling auxiliaries consist of: conveyor, drag scraper, tail car, tripper, and miscellaneous units

balance relays select the faulty line. A voltage relay in the neutral of a 110 kv capacitor potential device will trip the line for a phase-to-ground fault. For grounds on the 22 kv windings of the transformers a directional ground relay is used.

Outgoing 22 kv feeder circuits are equipped with inverse-time-delay overcurrent relays for phase-to-phase faults and an instantaneous overcurrent relay for phase-to-ground faults. Inasmuch as the 22 kv feeders all consist of shielded-type 3-conductor lead-covered cables the fault is invariably of the phase-to-ground type, which is cleared instantly and without noticeable effect on the system. The overcurrent phase relays serve principally as back-up protection for faults in the substations.

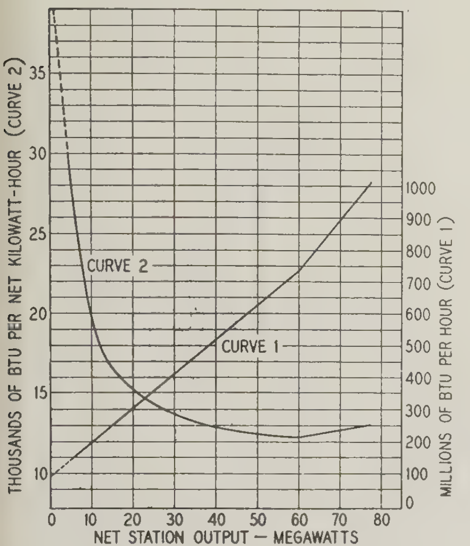


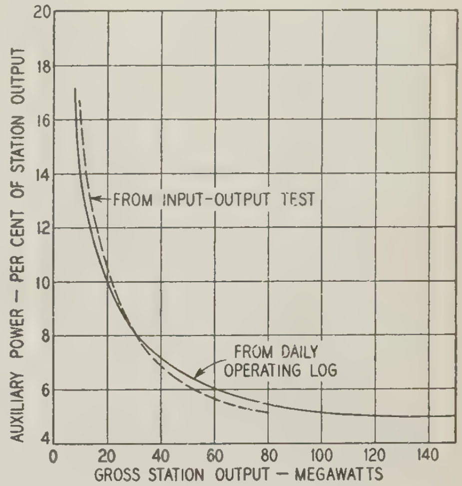
Fig. 12. Energy consumption curves obtained during over-all input-output tests

Auxiliary Power Equipment

Auxiliary power is obtained from the 12 kv terminals of the generators with a reserve supply from the main station busses. Where a station is a part of a large interconnected system with multiple ties to the system, this method of obtaining auxiliary service was considered justifiable in view of its advantages over other schemes, namely, low capital cost, low operating cost, and simplified operation. Figure 11 shows the connections.

The proper voltage for the auxiliary motors is usually a difficult problem to decide. Many elements influence this, among which are, motor sizes, motor and control equipment costs, the connection diagram, and the amount of reserve transformer capacity required. For this station a thorough study showed that a single 550 volt system would have decided advantages over a 440 or 2,200 volt system, or a combination of both, especially in over-all cost, simplicity, and reliability.

Fig. 13. Auxiliary power versus net station output



Because of the large size of the turbogenerators and boilers, the auxiliaries for each were divided into 2 groups, for example, 2 induced draft fans per boiler, 2 circulating water pumps per turbine, etc., the groups being designated *A* and *B*. The miscellaneous motors make up the *N* group. There are 5 major groups of motors, namely, 1*A*, 1*B*, 2*A*, 2*B*, and *N*, each connected to a unit bus similarly named. A separate transformer supplies each of these busses, 2 of which are connected to the 12 kv terminals of generator 1, 2 to the 12 kv terminals of generator 2, and 1 to the 22 kv bus. Two additional transformers, each connected to a separate 22 kv bus, supply a 550 volt reserve bus to which any of the unit busses may be transferred. The control is arranged so that if the voltage on an *A* or *B* bus should fall to a value 50 per cent or more below the voltage of the reserve bus, an automatic transfer will be initiated after a period of 2 seconds; in this transfer the normal supply circuit breaker will

Table II—Over-All Operating Performance of Huntley Station No. 2

		Turbines						Boilers				
Year	Months	Net Megawatt-Hours	1,000 Pounds of Coal Burned	Avg Net Generation, Megawatts	Net Station Capacity Factor	Number of Starts	Net Turbine Water Rate	Number of Starts	Banked Hours	Active Hours	Evaporation, Pounds of Steam per Pound of Coal	Btu per Net Kilowatt-Hour
1930	2½	44,505	48,389	23.8	29.7		11.09		508	1,857	9.18	14,971
1931	12	94,934	136,302	13.2	8.3	114	11.30	2,578	12,215	8,890	8.52	18,721
1932	12	80,069	130,291	9.1	5.7	71	13.00	2,922	12,657	12,639	8.50	19,973
1933	1st 5	29,976	50,031	8.2	5.1	6	13.38	1,328	6,181	4,698	9.12	21,130
1933	Last 7	330,890	346,708	64.5	40.3	97	10.65	1,442	5,369	13,966	10.77	13,812
1933	12	360,866	396,739	41.2	25.8	103	10.88	2,770	11,550	18,664	10.31	14,467
1934	12	314,667	345,527	35.9	22.5	125	10.88	2,901	12,995	16,282	10.12	14,470

be tripped and the breaker to the reserve bus closed, thus retaining the auxiliaries in service and thereby maintaining the same rate of boiler steaming capacity.

A 550 volt system for the auxiliary motors permitted the use of simple and rugged equipment of

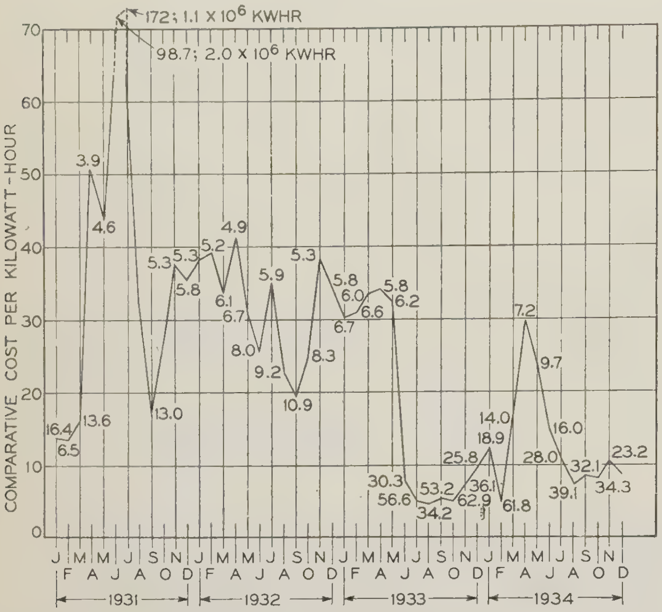


Fig. 14. Total monthly costs, including maintenance and fixed charges, for the first 4 years of operation of Huntley station No. 2. Figures at each point designate the monthly output in millions of kilowatt-hours

the 600 volt class. Air circuit breakers with silver faced main contacts and phase barriers were provided for the transformers and for all the motors or groups of motors supplied directly from the main 550 volt busses. For the various motors in the subgroups special latched-in contactors were used, enclosed in steel cubicles and located near the load centers. One of the criterions in the layout of the auxiliary equipment was to locate the transformers and busses as close to the load as possible to avoid long feeders. It may be noted that the main transformers are placed directly below the 550 volt switch rooms and that the latter are located centrally within the cross section of the station.

Each motor was selected for its specific duty, fully enclosed or drip proof as required, with special insulation, etc. Motors on the air heater floor are cooled by drawing cool air from the roof and discharging it into the room.

Fault protection of the auxiliary motors is of the simplest possible type. Each 550 volt feeder was equipped with overcurrent instantaneous relays which operate on short-circuit current only. None of the essential motors have overload or thermal protection. No protection of any kind is provided for the individual motors in the boiler or generator subgroups; a fault in one of these motors will cause the opening of the main circuit breaker supplying the group. If a fault should occur on a 550 volt unit bus, overcurrent relays will trip the normal supply breaker and lockout relays will prevent an automatic transfer to the reserve bus. Ground detectors are provided for the 550 volt busses, which will indicate a ground and usually permit its removal before the development of more serious trouble.

Construction Costs

Construction costs of the 160,000 kw Huntley station No. 2 were divided as follows:

Item	Per Cent of Total Cost	Item	Per Cent of Total Cost
Land	1.4	Turbogenerator and condenser equipment	17.7
Ground improvements	1.3	Boiler house equipment	19.3
Intake and discharge tunnels	*4.4	Piping	3.9
Main buildings with their foundations	15.9	House service equipment	4.6
Coal handling equipment	†12.1	Miscellaneous equipment	0.8
22 and 110 kv electric feeders	8.4	Construction expense and overheads	10.2

* Intake tunnels were designed to handle the requirements of a plant with an ultimate installed capacity of 1,000,000 kw; also the figure includes the cost of extending the discharge tunnel of the 305,000 kw adjacent plant to the down-stream side of the new intake.

† This figure includes the total cost of a car dumper, boat unloading tower, and necessary conveyors, which serve both plants.

Operating Results

The degree to which the design described meets the requirements may be judged from the results of input-output tests on the whole plant and from the records of 4 years' operation. During August 1932, an over-all plant test was made using 2 boilers and one turbine. The coal input was measured by the automatic scales located above the coal feeders,

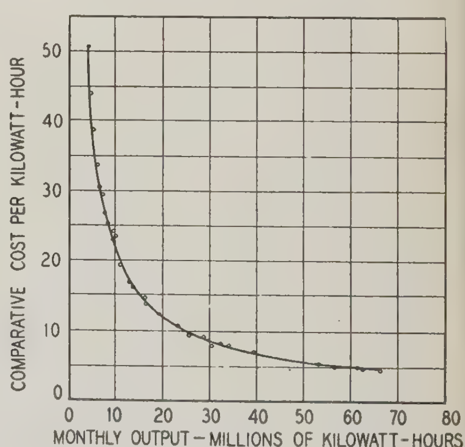


Fig. 15. Data of figure 14 replotted in different form

and the net electric output of the plant was read on station meters. These devices were carefully calibrated before the test. Raw coal samples were obtained in approved manner and carefully analyzed. Each of the 5, 10, 20, and 30 megawatt loads was held constant for 24 hours; the 40 megawatt load for 15 hours; and the 60 and 80 megawatt loads for 9 hours each. The results of this test are

shown in the curves of figure 12. No-load losses for one turbine and 2 boilers including station lighting and miscellaneous power amounted to 91,000,000 Btu total furnace input per hour. The auxiliary power required is shown in figure 13. It may be of interest to know that the power required by the pulverizers with full load on the station is $^1/_2$ of 1 per cent of the generated power (10 per cent of the total auxiliary power).

An idea of the wide range of loading imposed upon the plant can be obtained from figure 6, which shows typical daily loads, and from table I, which shows the turbine loading for the 4 year period. Table II shows how the plant has performed under these severe operating conditions. The year 1932, with a capacity factor of 5.7 per cent was the low output year for the plant. For the first 5 months of 1933 the average station output was 8.2 megawatts with a net heat rate of 21,130 Btu in contrast with the last 7 months of the same year, in which the average was 64.5 megawatts and the net heat rate 13,812 Btu.

The total monthly costs per kilowatt-hour (operation, maintenance, and fixed charges) for the entire period of operation to January 1, 1935, is shown in log form in figure 14. Figure 15 shows the data of figure 14 replotted using monthly output for one of the co-ordinates. While this station was designed for a relatively low capacity factor (25 per cent or less) the results indicate that the economy is well in line with plants having an even higher steam pressure.

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Photoelectric Control of Resistance Type Metal Heaters

Manually operated resistance type metal heaters, which heat the metal by passing current directly through it, have been in use for several years. Automatic machines of this type have now become practical due to the development of photoelectric temperature control. Results with photoelectric control are shown to be highly satisfactory.

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RESISTANCE type electric heaters, in which the material under treatment is heated directly by the electric current being passed through it, are coming into prominence for purposes of heating metal bars, rods, rivets, and other similar parts to a heat treating or forging temperature. The proper control of these heaters so that power is cut off and the part ejected at the proper temperature is important.

A resistance type heater consists of a power transformer which steps the line voltage down to a few volts, conducting electrodes for gripping the material and conducting the current to it, and mechanism for operating these electrodes. The control is very simple for a manually operated machine, but for fully automatic machines the use of more elaborate and accurate equipment may be necessary.

A photoelectric controller which has been developed for resistance type heaters is described in this paper. Radiation from the material being heated operates a photoelectric tube which, when the proper temperature has been reached, operates through an amplifying tube and other devices to shut off the current, eject the material from the heater, and start another cycle of operation on a new piece of material.

Features of the apparatus described in this paper are as follows:

1. The operation of the automatic heating equipment described herein proves that the photoelectric method of temperature control is entirely satisfactory.

2. Increased production above that possible with manually operated heaters may be expected. Consistency of temperature control including the normal variations in tube characteristics has been proved.

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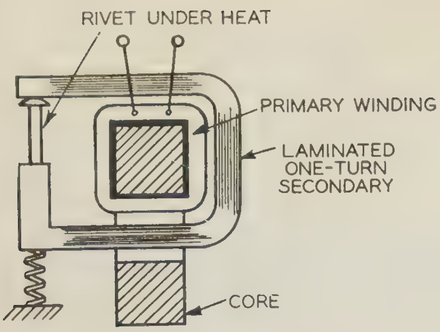
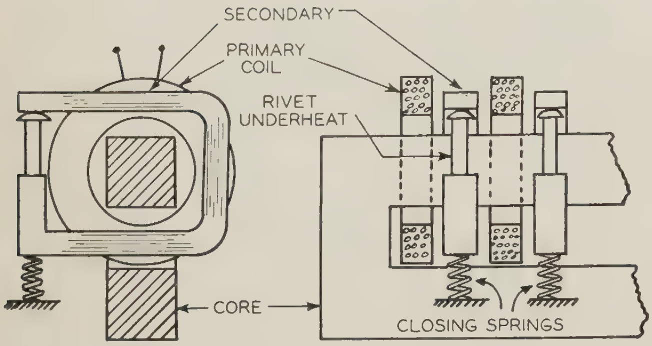


Fig. 1 (left). An early design of rivet heater

Fig. 2 (below). A present day rivet heater



Under average operating conditions the trip point may be expected to remain within 50 degrees Fahrenheit after having been set by use of a pyrometer as a standard.

3. It is obvious that better temperature regulation is possible than by manual control, for the human element is eliminated. Accordingly, less rejections caused by improper heating conditions may be expected.

4. Automatic operation of equipment reduces material handling time, thereby resulting in a proportionate production increase and lowered cost through reduction of labor charges.

5. The photoelectric method of control may also be used for control of other methods of heating such as furnaces and inductive heaters.

Development of Various Types of Heaters

The electrical heating of metals by passing current through the part to be heated is not a new process, but the development of satisfactory, and, at the same time, rugged equipment, has been tedious and difficult. The rivet heater brought out in 1913 by a manufacturer with which one of the authors is connected, has now been developed to the present fully automatic, temperature controlled heater for use in forging and heat-treating.

The original heater consisted of a transformer, having a low-voltage high-current secondary winding of one turn placed directly over the primary winding as shown in figure 1. The metal to be heated was inserted in the secondary circuit and held in place by spring pressure on the electrodes. This type of heater has been materially improved upon. The succeeding design makes use of several pancake type primary windings, while the one-turn secondaries are sandwiched between the primary coils, as shown in figure 2. This is the type of design in general use today in fabricating shops and for bridge construction where rivets are to be heated.

With the development and sale of the rivet heater,

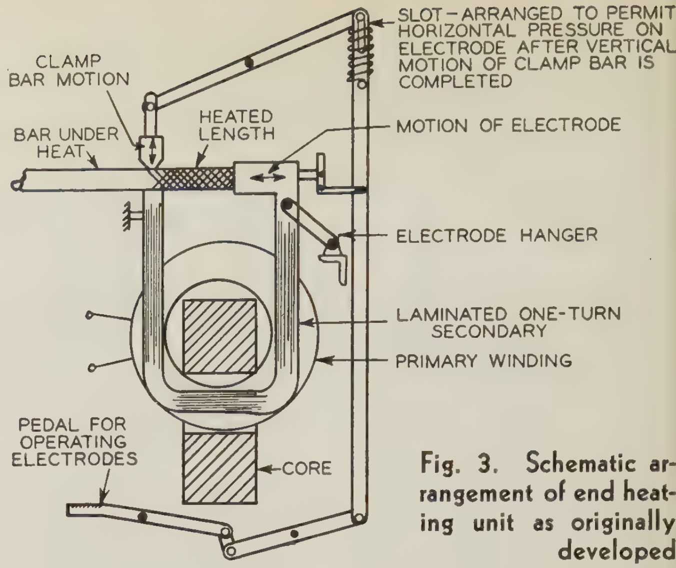


Fig. 3. Schematic arrangement of end heating unit as originally developed

came that knowledge of the art which led to its application in other fields, principally in the heating of materials for forging, bending, heat-treating, etc. To meet the demands thus imposed, many heaters of different types were constructed, each meeting a definite requirement.

For example, heaters have been constructed for the end heating of the various length blanks used in cutlery manufacture, for the end heating of wheel spoke blanks and for upsetting bolt heads. Such heaters usually have embodied the side to end method, figure 3, or the 2 path secondary principle, figure 4. The heating current either enters the bar at a point or points on its perimeter and leaves at the bar end, or enters and leaves at different points on the perimeter only.

Heaters have been constructed for the forging of

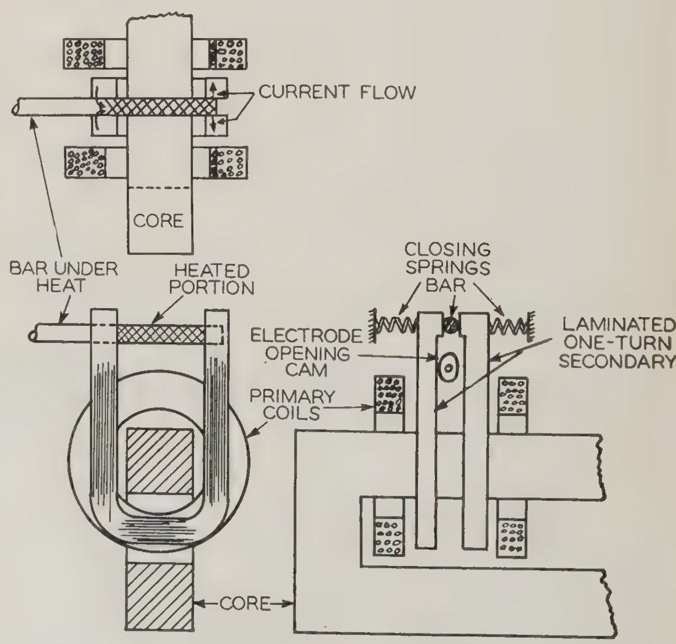


Fig. 4. Arrangement of principal parts of a 2 path heater representing the first design from which the present fully automatic machine has evolved

automobile valves, as well as the heat-treatment of valve stems and other intricate parts. However, in the heating of such stock—and it should be recognized that a satisfactory end heat is difficult to obtain—it is usually necessary to avoid the marring of the blank sidewalls. Particularly is this true on automotive and bolt blank stock. Marring or pitting is eliminated by the use of limit switches, mechanically operated, and actuating the main contactor in such manner as to assure no power being supplied to the transformer until the material has been securely gripped between the electrodes; and further, that power be cut off previous to any attempt to break contact between bar and electrode.

However, the use of the electric heater in the field of heat-treating and in the forging of alloy steels demands a definite control of temperature. This can be accomplished best by shutting off the current to the primary of the transformer at the instant that the proper temperature is reached. Various schemes proposed heretofore are:

1. Magnifying leverages operated by expansion of the bar under heat.
2. A bimetal strip located close to the side of the bar, which would bend and close contacts due to absorption of radiated heat.
3. A time delay relay connected to apply power to the transformer for a measured length of time only. This is unsatisfactory due to varying time, voltage, and electrode-bar contact resistance.

Photoelectric Scheme of Control

A fourth method, and the one to be described in this paper involves the use of a photoelectric controller which has been developed. The photoelectric tube, which is the sensitive element, is mounted so that the energy radiated from the bar is focused on it. This development has been very important in extending the field of heater application by making a fully automatic or semiautomatic heater practical for the first time.

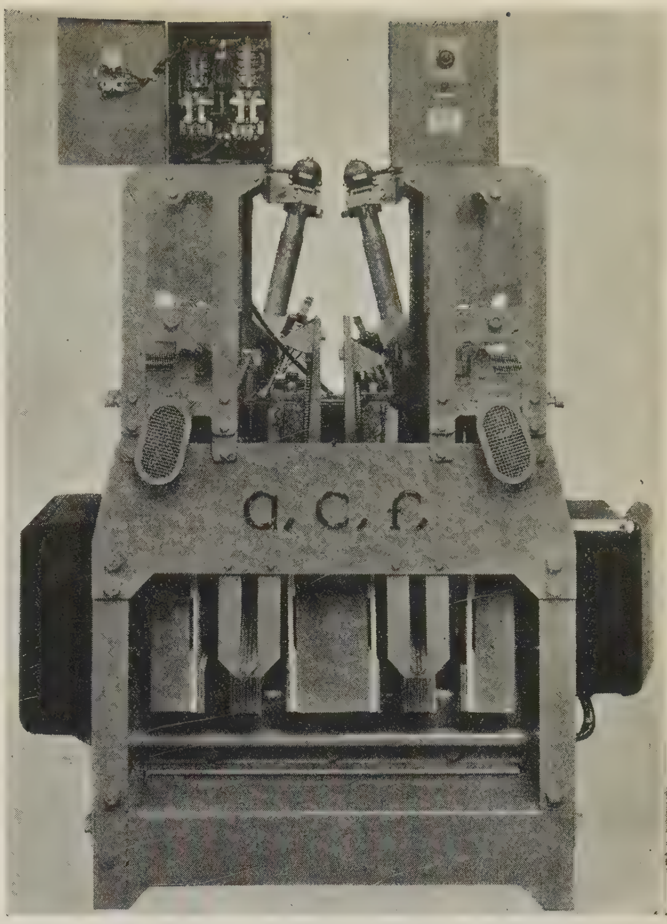


Fig. 6. A 2 unit automatic heater with photoelectric control

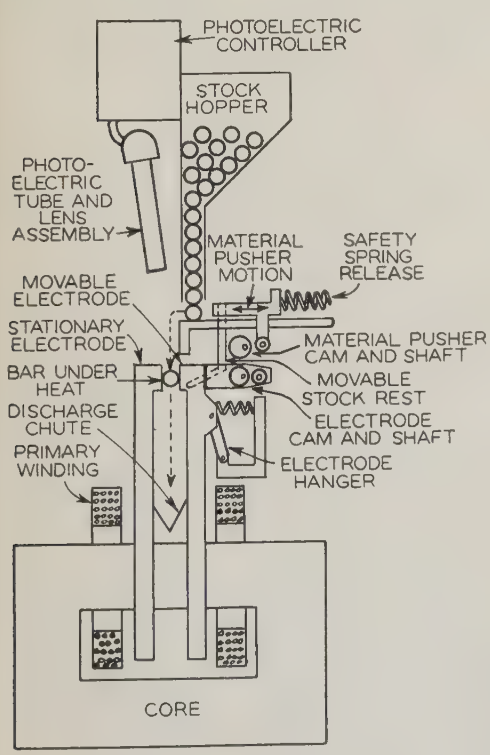


Fig. 5. Schematic arrangement of heater arranged for full automatic operation

A general idea of the principles involved in the automatic type of heater is obtainable from figures 5 and 6. The mechanical operations are rather simple. Material to be heated is loaded into a stock hopper, from which it is led vertically downward to a shelf, from whence, as needed, it is pushed laterally one piece at a time and falls to a movable stock rest between the open electrodes, which are then closed, and power is applied. Upon heating to the proper temperature, as determined by the setting of the photoelectric control, the power is cut off the transformer, the electrodes are opened automatically, the hot piece discharged, and another cold blank drops into place, and the cycle of operation is repeated.

Description and Characteristics of Equipment

The photoelectric tube is an electronic tube which conducts current in proportion to the quantity (lumens) of light projected on its cathode.

If the temperature of a body is raised, the total energy radiated to other bodies increases as a fourth power function of the absolute temperature. The spectral distribution of the energy radiated depends upon the temperature of the body. Much more energy of short wave lengths is radiated as the temperature of the body is increased. A continuous in-

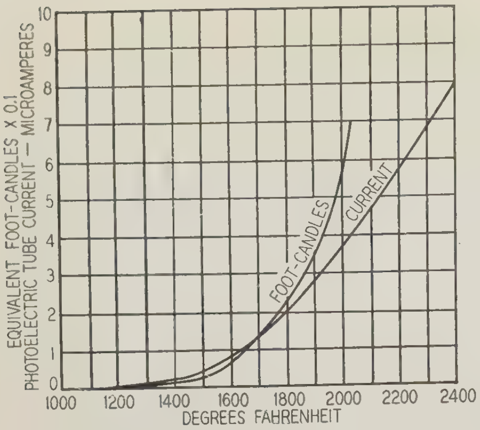


Fig. 7. Curves of test data showing photoelectric tube current for various temperatures and the footcandles from a standard lamp at 2,870 degrees Kelvin required to produce that current

All tests made on nichrome bar with an arbitrary optical system and an average photoelectric tube, all representative of the design of photoelectric controller in figure 9. Other metals less similar to a black body, such as aluminum, produce less response

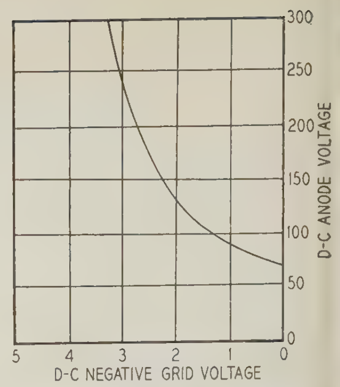


Fig. 8. The grid control characteristic of the grid-controlled gas-filled tube used

crease in temperature results in radiation of red light visible to the eye at a temperature of about 1,200 to 1,300 degrees Fahrenheit.

Commercial photoelectric tubes have a color sensitivity curve such that the first appreciable photoelectric current due to radiated energy received from a heated body occurs at a body temperature of about 1,150 degrees Fahrenheit. As the temperature of the body is increased further, the equivalent light on the photoelectric tube cathode increases rapidly as a power function of the temperature rise above 1,150 degrees Fahrenheit; this is shown in figure 7. The same figure shows the photoelectric tube current in microamperes. This curve was taken using a photoelectric tube of average sensitivity connected in series with a 10 megohm resistor and with a supply voltage of 90 volts direct current. These conditions are identical with those in the photoelectric control equipment.

Since the photoelectric current is not sufficient to operate a magnetic relay, an electronic tube of the grid-controlled gas or mercury vapor filled type is connected to function as a sensitive relay. When the proper temperature is reached, the voltage drop over the resistor in series with the photoelectric tube causes the grid-controlled gas-filled tube to conduct and energize the control contactors.

The grid-controlled gas-filled tube has a grid control characteristic as shown in figure 8. This characteristic shows the grid voltage which will cause the tube to start and conduct current for various values of anode-cathode voltage. It is seen from the circuit of the photoelectric controller, figure 10, that the anode voltage E_a is alternating current. The critical grid voltage which will permit the grid controlled tube to start at various times during the half cycle of anode voltage when the anode is positive with respect to the cathode is shown in figure 11, curve e_c. When the photoelectric tube T_2 is dark, there is no voltage drop over resistors R_1 and R_2, and the voltage e_g between grid and cathode consists of the adjustable d-c voltage E_b plus the phase shifted voltage E_{ps}. The voltage divider P is so adjusted that the total grid voltage curve e_g does not intersect the critical bias curve e_c. When the photoelectric

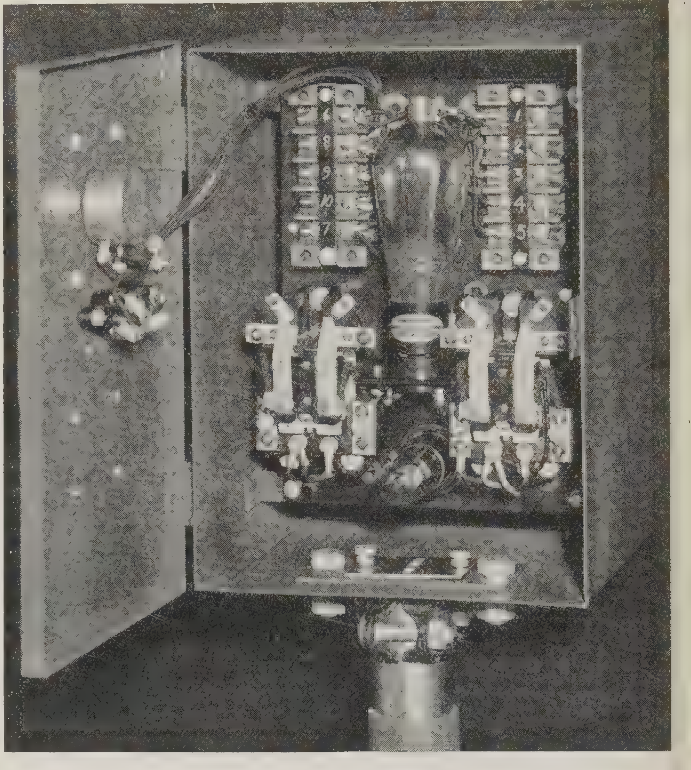


Fig. 9. The photoelectric controller used for temperature control

tube T_2 is illuminated by the radiation from the heating metal, it conducts current and thus produces a voltage drop E_r over resistor R_1 of the polarity shown. When E_r reaches the value shown in figure 11, the net grid voltage curve E_{pt} intersects the critical bias curve e_c at point C and causes the grid-controlled tube T_1 to start. T_1 then conducts current during the remainder of the half cycle as shown in the shaded portion of figure 11. The conduction of current by the tube T_1 energizes contactors 1 and 2 which close and are interlocked by contacts 1 through the "reset" push button PB_1 and the limit switch LS_1. The interlock circuit has low enough voltage drop so that tube T_1 is stopped, thus reducing the operating time of the tube and increasing its stability and life. The interlock also prevents contactors 1 and 2 from opening because of reduction of illumination on the photoelectric tube cathode when the power is shut off and the hot metal removed.

The phase shifted voltage E_{ps} is superimposed on the d-c voltage E_b to cause tube T_1 to start early in

the positive half cycle of anode voltage. Without E_{ps}, tube T_1 would start at the middle of the half cycle as E_b would intersect e_c at its midpoint due to increase of E_R. This is not desirable as maximum current will not flow in the coils of contactors 1 and 2 until the photoelectric tube T_2 is illuminated enough more to shift the point of intersection of E_{pt} with E_c to point C.

Sequence of Operation

The complete sequence of operation of one unit of the 2 unit automatic heater, figures 5 and 6, is readily visualized by reference to figure 10. Let it be assumed that the machine is being started with the electrodes closed but with no material between them, and that contactors 1 and 2 are open. The bar pusher is under the hopper spout and a bar is in position in the spout. When the push button PB_2 is depressed, contactors 1 and 2 are closed, thus energizing the motor through contacts 2. The motor is directly coupled to the electrode cam shaft. As this shaft starts to revolve, the electrodes are forced open against spring pressure and at the same time the bar feed cams, mounted on a shaft geared to the electrode cam shaft, drop off their high points permitting springs to force the pusher bar forward. The bar stock being pushed out reaches the edge of the shelf at the same instant that the electrodes reach their fully open position. When the bar is pushed past the edge, it falls between the electrodes. As the pusher bar moves forward, a movable stock rest attached to the pusher bar moves forward with it, but slightly in advance, so as to be in position to catch the bar.

As the shafts continue to revolve, the electrode cams drop off their high points, permitting springs to close the electrodes and grip the bar. At the same time, the bar feed cams return the movable rest and the bar pusher to their original positions, thus leaving the way clear for the bar to drop to the discharge chute when released by the electrodes.

As soon as the electrodes have gripped the bar and the movable rest is under the shelf, the motor switch cam which is mounted on the electrode shaft breaks the contact in a normally closed limit switch *LS-1*. The opening of *LS-1* de-energizes contactors 1 and 2 thus stopping the motor and energizing the transformer by operation of contactor 3. The motor is stopped almost instantaneously by a magnetic brake. A 5 or 6 degree drift of the motor permits *LS-1* to reclose.

The bar now heats to a predetermined temperature which will cause the photoelectric controller to operate as previously described, energizing contactors 1 and 2. Their closure opens contactor 3, de-energizes the transformer and closes the motor circuit, thus starting a new cycle of operation.

As the electrodes release the bars, the limit switch *LS-2* is closed by a cam on the electrode shaft. This energizes the kicker solenoid which forces a plunger

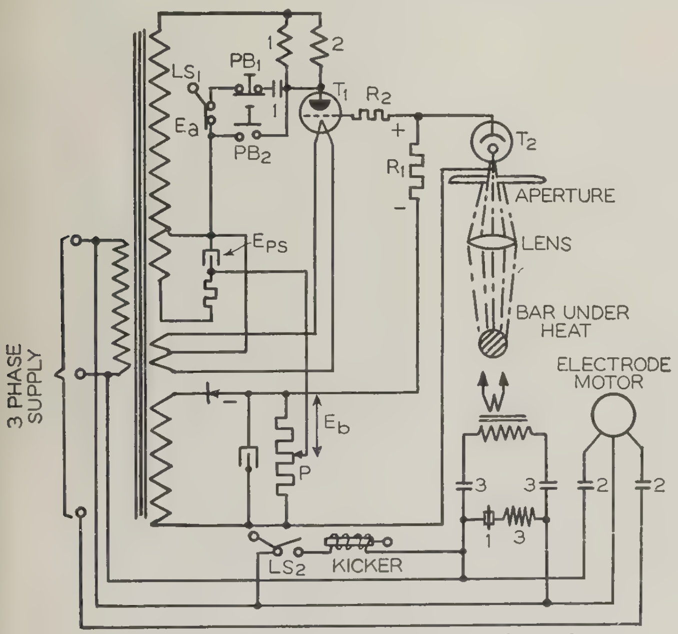


Fig. 10. Schematic circuit diagram of photoelectric controller and heater control

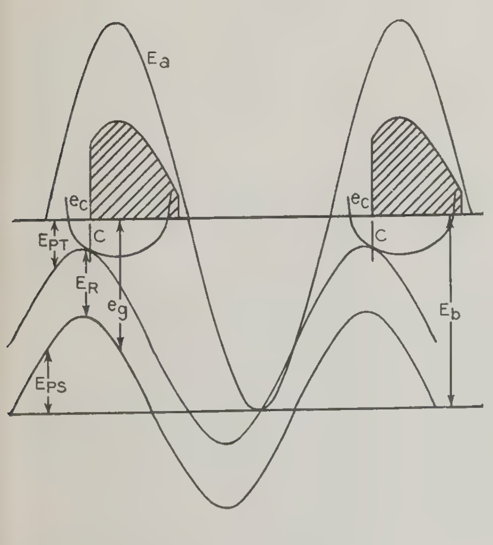


Fig. 11. Voltage relations in circuit of figure 10

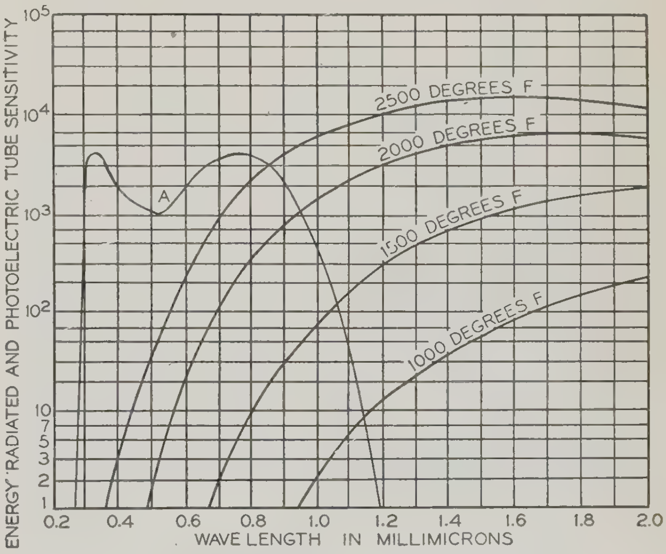


Fig. 12. Curves showing relative energy radiated by a hot body at various temperatures and wave lengths. The color response curve A of the photoelectric tube is also shown. All curves are to an arbitrary scale of ordinates

against the bar at the moment of its release. This prevents any trouble which might be caused by occasional sticking of the bar to the electrodes.

Range of Operating Temperature

There is practically no upper limit of operating temperature as this is readily increased by masking a greater portion of the light from the photoelectric tube. The unit shown in figure 9 will operate reliably at temperatures as low as 1,500 degrees Fahrenheit and has an approximate range of adjustment as shown in figure 14 when no mask or aperture is used.

The minimum operating temperature is established by the lack of sensitivity of commercial photoelectric tubes to the radiated energy at long wave lengths beyond 1.2 millimicrons. (One millimicron represents a wave length of one-millionth of one meter.) The color characteristic of an average photoelectric tube of the caesium-oxide type is shown in curve *A* of figure 12. The spectral distribution of energy radiated from an ideal black body at various temperatures is given in the same figure to show how rapidly the energy radiated at wave lengths to which the photoelectric tube is responsive is reduced as the temperature of the body is decreased. The parts of the curves which overlap represent the sensitive range of wave lengths. The product of the ordinates of the photoelectric color response curve and the spectral energy curve at a given wave length is proportional to the photoelectric sensitivity for that wave length. The products obtained at various wave lengths form a spectral luminosity curve for the photoelectric tube as shown in figure 13 for various temperatures. The product of the area under the spectral luminosity curve and an empirical constant gives the photoelectric current for a given temperature, photoelectric tube, and optical system.

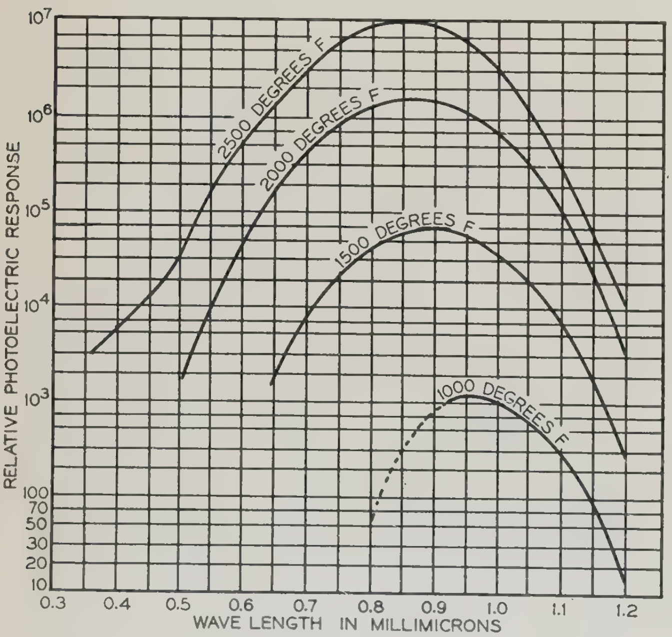


Fig. 13. Relative response of a caesium-oxide photoelectric tube at various temperatures and wave lengths. Calculated from data in figure 12

Considerable improvement in the response of photoelectric tubes to light of wave lengths up to 1.2 millimicron has been made. However, the threshold wave length of 1.2 millimicron has not been extended appreciably in any commercial photoelectric tube. Unless the threshold wave length can be extended into the long wave length region beyond 1.2 millimicron, the lower limit of operating temperature for any photoelectric device will be between 1,150 and 1,500 degrees Fahrenheit. The practical lower operating limit depends entirely upon the color sensitivity of the photoelectric tube used and the permissible amplification. Sufficient safety factor is included in the rating to insure operation with tubes having limiting color and sensitivity characteristics.

Other light sensitive devices such as the selenium cell and the "thalofide" cell have been investigated but do not appear to be as satisfactory as commercial caesium oxide photoelectric tubes.

Indicating elements other than the photoelectric tube have been considered, especially thermocouples mounted so that the radiation is focused on them by a lens. The thermocouple has the advantage of being responsive to the total energy received, and is not selective. The disadvantages of the thermocouple are numerous and appear to eliminate it from application at the present time. The thermocouple equipment is more expensive than the photoelectric control within the range of sensitivity of the latter. The thermocouple has considerable time lag, causing inaccurate control for rapid heating of small parts. At low temperatures outside the range of the photoelectric system, the thermocouple apparatus is not simple to design and build because of the low energy output from the thermocouple which must operate a contact making instrument. If a suitable system of thermocouple, contact making instrument, and control can be worked out, it may prove useful for temperatures lower than 1,500 degrees Fahrenheit.

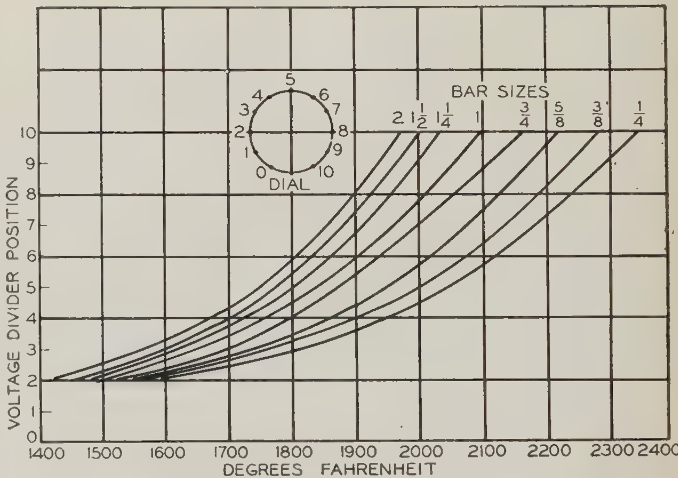


Fig. 14. Typical curves of voltage divider position versus temperature for several sizes of stainless steel round bar

The Sparkless Sphere Gap Voltmeter

Sphere gaps may be used for measuring very high voltages by holding them at a separation greater than spark-over distance, and measuring the force between them. The voltage may then be calculated easily and accurately from well known electrostatic principles. Among the advantages of this type of measurement over the conventional spark-over methods are: no corrections are necessary for air temperature, humidity, and pressure; effective voltage values are given; measurements are not erratic; and numerous difficulties in taking measurements are avoided.

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THE sphere gap may be used as a Kelvin electrostatic type of voltmeter rather than a spark gap voltmeter, if the spheres are mounted so that the forces between them, due to applied differences of potentials, can be measured; and the authors of this paper believe the data presented herein indicate greater convenience and accuracy for sphere gaps thus used than can be obtained with gaps used in the conventional manner. The reasons for this statement are:

1. Accurate methods are available for calculating the relation between potential differences of 2 isolated spheres and the forces due to these potential differences when sphere dimensions, spacing, and the dielectric constant of their ambient medium are known.

2. Since the dielectric constant of air is not appreciably affected by temperature, air density, or humidity, no corrections for these factors are necessary.

3. The tests showed complete freedom from erratic readings so noticeable in the spark gap voltmeter.

4. Test planes of large size placed as near as possible to the spheres without causing sparking from spheres to plane had little influence on the readings.

5. The sensitivity of equipment used is such that a change in force of $^1/_2$ gram or less can be detected easily, and forces from 100 to 400 grams were available in the tests. This degree of sensitivity is such that the instant of contact of the spheres at zero spacing can be noted by a movement of the free sphere more readily than by noting the electric contact or any other means known.

Apparatus Used

The apparatus used in the experiments is shown in figures 1, 2, and 3. The only large spheres available at California Institute of Technology for making these tests were a pair of 100 centimeter cast aluminum spheres made at the same time and as exact duplicates of the pair used by Carroll and Cozzens[1] in their tests; and these spheres show, on spark-over tests, the same erratic performance as reported by them. The right-hand sphere is supported by a rigid insulating frame suspended from the roof structure of the laboratory and is mounted in such a way as to provide for adjustment of the sphere gap for spacings from 0 to 150 centimeters. Changes in the sphere gap setting are made by means of a motor-driven mechanical system, the motor being placed on the floor and attached to, but insulated from, the sphere driving mechanism by a long rope belt. The left-

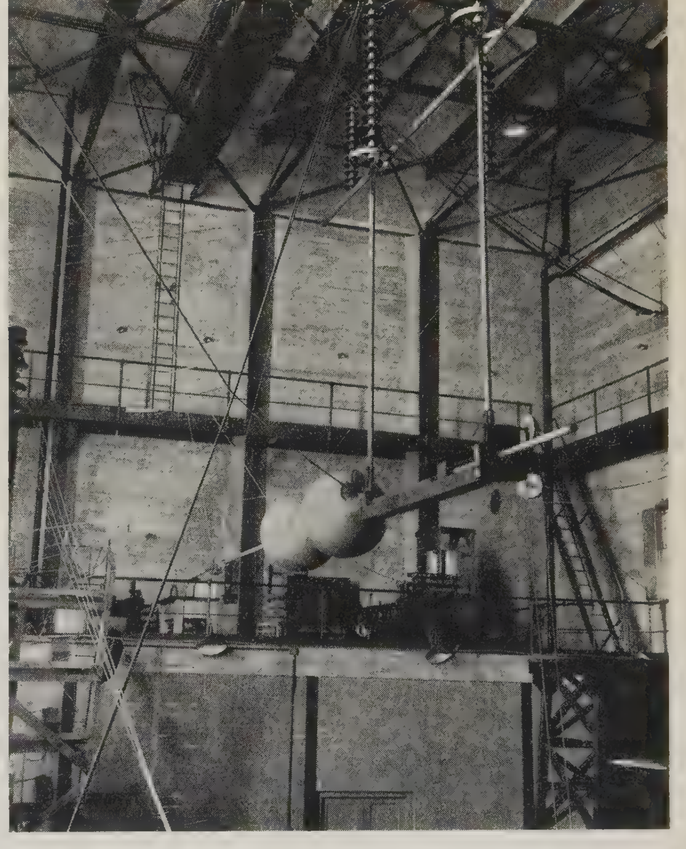

Fig. 1. A view of the sphere gap and other principal pieces of apparatus comprising the sparkless sphere gap voltmeter. The sphere in the foreground is the hot sphere. The measuring apparatus, shown in more detail in figure 3, may be seen at the far end of the shaft of the grounded sphere

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The authors acknowledge the assistance of Gilbert D. McCann, Louis T. Rader, Jack M. Roehm, and others working in the high voltage laboratory at the California Institute of Technology.

1. For all numbered references see list at end of paper.

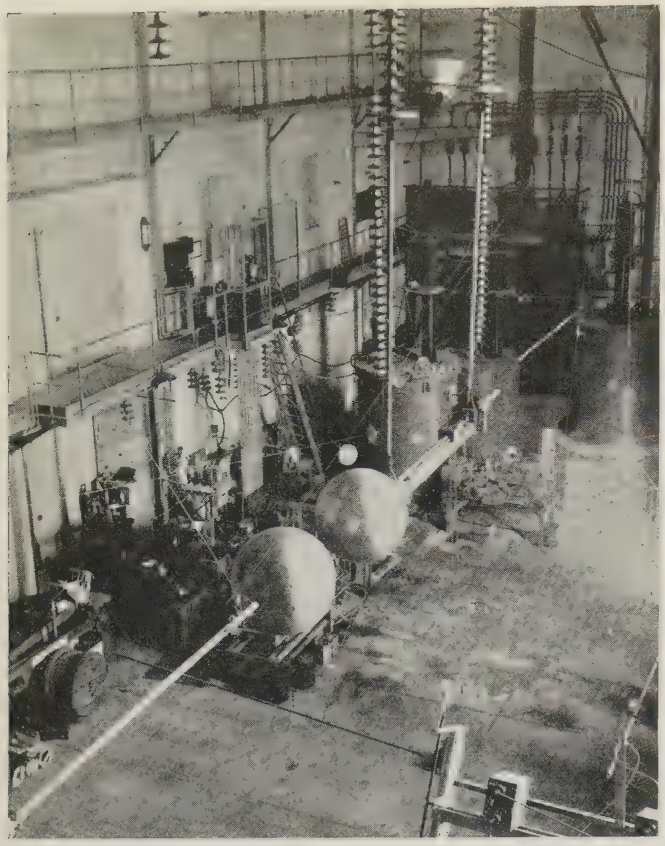


Fig. 2. Another view of the apparatus, showing the relation of the sphere gap to the other equipment in the laboratory, and showing the large clearance available around the gap. The grounded sphere is in the foreground of this view. Note the long V suspension ropes

hand or free sphere is suspended by 4 ropes arranged in 2 pairs, each pair forming a letter V, the apex of which is attached to the shaft supporting the free sphere. This suspension with the upper ends of the V attached to the roof structure provides horizontal force components which prevent lateral motion of the sphere and at the same time allows very free motion along the axis through the center of the 2 spheres. In the tests made, this free sphere was grounded by very flexible connections from its supporting shaft to ground. Mounted on this supporting shaft near the end away from the sphere, is a fine wire which serves as a pointer, any motion of which may be observed through a cathetometer telescope. Also at this end of the shaft, there is attached a cord which passes over a bicycle wheel used as a pulley and supports a weight pan on which weights may be placed to balance the pull between the spheres. With this arrangement the natural damping was sufficient to prevent oscillations.

A water tube resistance of about 2 megohms, made of $^3/_4$ inch garden hose through which tap water is run for cooling, is connected in the circuit between the transformers and the insulated sphere to prevent burning of the spheres when the gap flashes over. This resistance is kept insulated from ground by having the flowing water fall into a funnel at the top of the hose and from the outlet into a tank on the floor. The hose is protected from corona burns where necessary by pie tins used as disk shields spaced about 18 inches apart.

Taking Test Readings

In the work to date, readings of voltage have been made by setting the sphere gap just above spark-over distance for each voltage measured and enough weight put on the pan to balance the pull on the spheres and keep the free sphere from moving, as noted by the cross hair. With voltage held constant by means of a voltmeter in the transformer tertiary "volt" coil, the sphere gap distance was then decreased until the gap flashed over and the length of gap at the time of flashover noted. The potential difference for this spacing, as indicated by use of the A.I.E.E. sphere gap curve, may then be compared with the voltage calculated by the equation

$$V = 9{,}405\sqrt{F/S}$$

where F is the weight in grams on the pan, and S is the spacing factor shown in figure 8. Results of these measurements are shown in figure 4, typical data for which are given in table I.

V in the above equation is the effective value of voltage; hence, to compare it with the A.I.E.E. sphere gap curve, the wave form must be known. No difficulty was encountered at any time in duplicating readings showing the relation between the force readings as determined by the weights on the pan and the voltmeter readings as obtained at the "volt" coil; and the sensitivity and precision of the force measurements was found to be much better than the degree of accuracy obtainable in reading the voltmeter and setting the voltage control regulator. Figure 5 shows two 2 wave forms, the lower, the input volt wave to the testing transformer, and the upper one, the output voltage wave. The output wave was recorded by using a water tube resistance of about 5 megohms in series with an oscillograph; one end of the resistance being connected to the supporting shaft of the ungrounded sphere, and the other end connected through the

Table I—Typical Test Data for Voltage Measurement With One-Meter Spheres

Temperature "T" = 13 degrees centigrade
Barometric Pressure "b" = 747 mm of mercury

$$\delta = \frac{0.392\ b}{273 + T} = 1.023$$

Reading Number	Gap Setting for Force Measurement	Force in Grams	Tertiary Voltmeter Reading	Spark-Over Distance	Spark-Over Distance Corrected	S	Calculated Voltage*
2	35 cm	346.1	150	31.1 cm	32.1 cm	0.11082	526,000
3	40 cm	376.6	170	36.6 cm	37.9 cm	0.09174	603,000
5	50 cm	354.7	190.5	43.8 cm	45.4 cm	0.06592	690,000
7	55 cm	362.5	202	51.7 cm	53.7 cm	0.05693	750,000
10	65 cm	338.9	220	62.7 cm	65.4 cm	0.04363	829,000
13	70 cm	309.1	224	65.8 cm	68.4 cm	0.03863	840,000

* Calculated by equation: $V = 9{,}405\sqrt{F/S}$

oscillograph element to ground. An analysis of the output wave, using 50 ordinates, shows its root mean square value to be 99.25 per cent that of a true sine wave having the same crest value. Figure 5 shows the wave form is practically a sine wave.

Relation of Force to Voltage

The use of inverted images for calculating the force between 2 spheres may perhaps be more readily understood by considering the case for a point charge in the presence of a grounded conducting sphere isolated in space.[2,3,8]

When no other body is present, the potential at any point a distance r from the point charge q is $V = q/r$ which equation satisfies the one boundary condition that the potential be zero at an infinite distance from the charge. When the grounded sphere is introduced, the equation for potential at any point in space must satisfy the additional condition that the potential is zero at every point on the sphere. Simple geometry provides the equation for V which will satisfy these conditions.

In figure 6, o is the center of a sphere of radius a; charge q is a distance f from o; p' is a point on the line op at a distance d from o; s is any point on the surface of the sphere. From the figure,

$$r = \sqrt{a^2 + f^2 - 2af\cos\theta}$$

and

$$r' = \sqrt{a^2 + d^2 - 2ad\cos\theta}$$

If d is made equal to a^2/f:

$$r' = \sqrt{a^2 + \frac{a^4}{f^2} - 2\frac{a^3}{f}\cos\theta}$$

$$= \frac{a}{f}\sqrt{a^2 + f^2 - 2af\cos\theta}$$

and

$$\frac{r'}{r} = \frac{a}{f} \quad \text{or} \quad \frac{1}{r} = \frac{a}{f}\cdot\frac{1}{r'}$$

With a charge q at point p and another charge $q' = -\frac{a}{f}\cdot q$ at point p', the expression for potential at any point in space a distance r from p and a distance

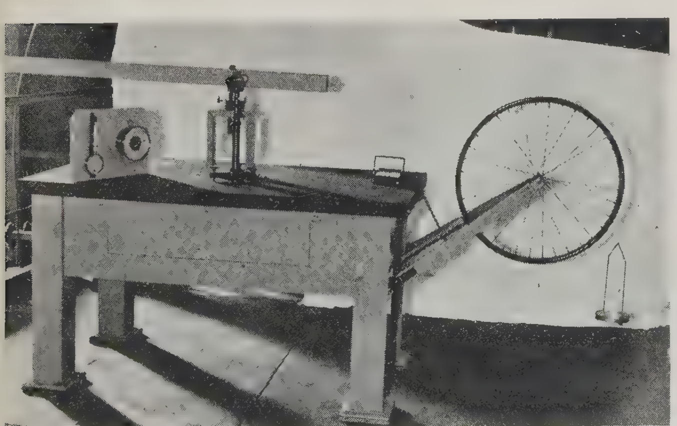


Fig. 3. A closeup view of the measuring apparatus

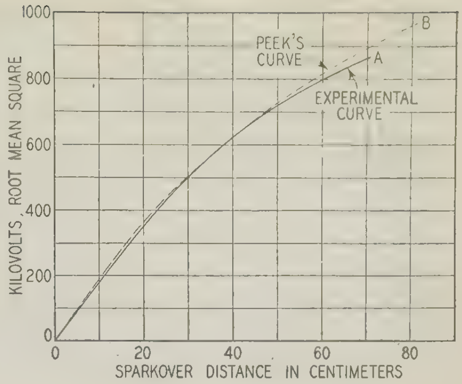


Fig. 4. Relation between spark-over voltage (effective) and sphere gap setting at spark-over distances

Curve A from force measurement data
Curve B from Peek's values for 100 centimeter spheres

r' from p' would satisfy the condition that the potential be zero on the surface of the sphere; since

$$V = \frac{q}{r} + \frac{q'}{r'} = q\left[\frac{1}{r} - \frac{a}{f}\cdot\frac{1}{r'}\right]$$

and

$$\frac{1}{r} = \frac{a}{f}\cdot\frac{1}{r'}$$

everywhere on the sphere.

Point p' is the inverted image point of p and the above expression for potential completely defines the field outside the sphere. The field outside a grounded sphere due to an adjacent point charge is the same as the field caused by the original point charge and its image point charge. The image charge is always $(-a/f)$ times the original charge and is located a distance a^2/f from the center of the sphere.

This analysis can be extended to show the field about a sphere A at a potential V in the presence of another sphere B at ground potential. The field outside an isolated sphere A at a potential V is equal to that due to a charge $q_1 = aV$ at the center of the sphere, where a is the radius which for a sphere is equal to its capacitance. If, as in figure 7, another sphere B, of the same radius and grounded, is brought into the field with its center a distance c from the center of A, the field will be distorted. But, as has been shown, a charge $q_2 = -\frac{a}{c}q_1$ at a distance $d_2 = \frac{a^2}{c}$ from the center of the grounded sphere B will, together with the original charge q_1 in the equation, give zero potential over the surface of sphere B. This new expression, however, no longer satisfies the condition that the voltage be equal to V over the surface of sphere A and it is necessary to cancel the effect on sphere A of the added charge q_2 by placing its image charge q_3 at a distance d_3 from the sphere center. If q_3 is the inverted image of q_2, that is, if $q_3 = -\frac{a}{c-d_2}q_2$ and $d_3 = \frac{a^2}{c-d_2}$ the resulting potential on sphere A due to q_2 and q_3 will be zero and the sphere potential will be the desired value V due to q_1 only. To keep B at zero potential under the influence of q_1, q_2, and q_3, this new charge q_3 must be imaged by a charge q_4 in B at a distance $d_4 = \frac{a^2}{c-d_3}$

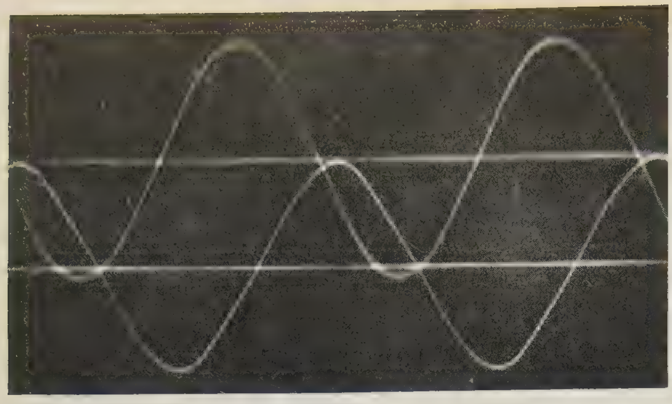


Fig. 5. Oscillogram of voltage, showing wave form

The upper curve shows the form of the voltage applied to the sphere gap
The lower curve shows the form of the voltage applied to the primary of the transformer

from the center of B. The value of q_4 is $-\dfrac{a}{c-d_3}q_3$ to satisfy boundary conditions. Thus a double series of images is set up, all those in sphere A having the same sign and all those in sphere B having the opposite sign to the original charge q_1.

In general $q_n = -\dfrac{a}{c-d_{n-1}}q_{n-1}$ and $d_n = \dfrac{a^2}{c-d_{n-1}}$

The total force on sphere B is then the sum of the attractions on each charge in B due to every charge

Table II—Calculated Images

Radius "a" = 50 centimeters Spacing = 30 centimeters

Sphere A (Potential V)		Sphere B (Potential Zero)	
$q_1 = Va$	$d_1 = 0$ cm	$q_2 = -0.385\ Va$	$d_2 = 19.2$ cm
$q_3 = 0.174\ Va$	$d_3 = 22.6$ cm	$q_4 = -0.086\ Va$	$d_4 = 23.2$ cm
$q_5 = 0.0378\ Va$	$d_5 = 23.4$ cm	$q_6 = -0.0177\ Va$	$d_6 = 23.45$ cm
$q_7 = 0.00833\ Va$	$d_7 = 23.5$ cm	$q_8 = -0.00393\ Va$	$d_8 = 23.55$ cm

in A. Since the attraction between 2 charges q_s and q_t a distance f apart is $\dfrac{q_s q_t}{f^2}$ the total force on B may be expressed as a summation:

$$F = \sum_{\substack{s=2\\ \text{(even)}}}^{\infty} \sum_{\substack{t=1\\ \text{(odd)}}}^{\infty} \frac{q_s q_t}{(c-d_s-d_t)^2}$$

Since c, even for very small gap settings, must be at least twice a, the nth image charge is much smaller than the $(n-1)$th charge. The inclusion of more pairs of images contributes rapidly diminishing amounts to the total force. In any case it is necessary to take only as many images as are required to make sure the total force of all the neglected images will be less than the allowable error.

A calculation for a 100 centimeter sphere gap with a setting of 30 centimeters will illustrate the method. The first 4 pairs of images and the distance of each from the center of its respective sphere is given in table II.

The force, due to these 4 pairs of charges only, is then:

$$F = \frac{q_1q_2}{[130-d_2]^2} + \frac{q_3q_2}{[130-d_2-d_3]^2} + \frac{q_5q_2}{[130-d_2-d_5]^2} + \frac{q_7q_2}{[130-d_2-d_7]^2} +$$
$$\frac{q_1q_4}{[130-d_4]^2} + \frac{q_3q_4}{[130-d_4-d_3]^2} + \frac{q_5q_4}{[130-d_4-d_5]^2} + \frac{q_7q_4}{[130-d_4-d_7]^2} +$$
$$\frac{q_1q_6}{[130-d_6]^2} + \frac{q_3q_6}{[130-d_6-d_3]^2} + \frac{q_5q_6}{[130-d_6-d_5]^2} + \frac{q_7q_6}{[130-d_6-d_7]^2} +$$
$$\frac{q_1q_8}{[130-d_8]^2} + \frac{q_3q_8}{[130-d_8-d_3]^2} + \frac{q_5q_8}{[130-d_8-d_5]^2} + \frac{q_7q_8}{[130-d_8-d_7]^2}$$

Which, for $q_1 = aV$ (a being 50 centimeters) reduces to, if V is expressed in statvolts:

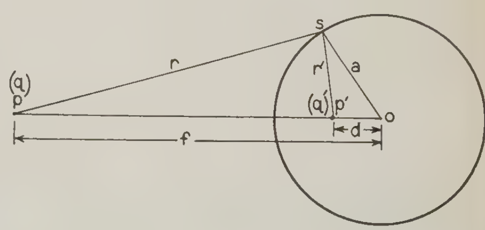
$F = 0.137V^2$ dynes

In general, $F = SV^2$ dynes for V expressed in statvolts or; $V = 9{,}405\sqrt{\dfrac{F}{S}}$ for V expressed in practical volts, and F in grams. With charges 7 and 8 neglected, the constant S would be reduced about one per cent, and, as their contribution to the total force is less than half the contribution of charges 5 and 6, the error made by neglecting all charges beyond 8 cannot exceed one per cent. The values for S, correct to the 5th decimal place, given in table III were computed with enough image charges to give this accuracy for spacings from 0 to 100 centimeters. These tabulated values are plotted in figure 8, and were used in conjunction with the force measurements to calculate the voltages for the one-meter spheres.

Since the larger the force measured, the smaller the experimental error, the gap should be set as small as possible without permitting flashover for each measured voltage. For flashover gap settings, using F. W. Peek's data[4] for the flashover of one-meter spheres, forces approximately those shown in figure 9 will be obtained.

Figure 10 shows for one-meter spheres the force as a function of voltage for sphere gap spacings of 15, 30, 50, 75, and 100 centimeters.

Fig. 6. Diagram representing a sphere and a point charge



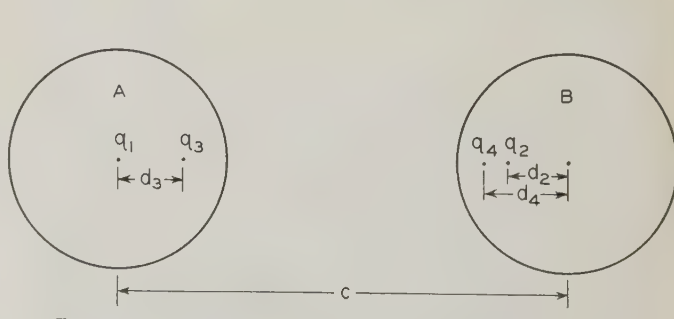


Fig. 7. Diagram representing 2 spheres, sphere A being at a potential V, and sphere B being at ground potential

In like manner, images may be used for the calculation of the influence of ground plane effects on the force between the spheres. The accurate calculation of such influence is possible, but laborious. To compute the change in the force caused by an infinite ground plane (for instance, a laboratory floor or wall), each charge of the original 2 infinite sets of images must be imaged to a position as far behind the plane as the charge lies in front of the plane. These 2 new sets of images must in turn be imaged back into the spheres following the law for sphere images presented above, each image being the origin of an infinite series of images in the spheres, and the procedure continued until the imaged charges become negligibly small. Consequently, the number of charges to be considered in calculating the force existing between the spheres is very much larger than for the case of isolated spheres.

Slide rule computations for the one-meter spheres set at 25 centimeters gap, were made of the disturbing effect of grounded infinite planes, one 20 feet from the gap, parallel to the line of the sphere centers, representing the laboratory floor; and the other 20 feet from the gap, perpendicular to the line of the sphere centers, representing an end wall. Since only an approximate indication of the disturbance was desired, image charges less than one per cent of the original charge were neglected; and charges located within a few centimeters of each other were grouped in a mean position when considering the forces exerted on them by charges several hundred centimeters distant. The result of these calculations indicated the error due to the assumption of isolated spheres to be of the order of 0.5 per cent. For the number of images considered in the computation, this is within slide rule accuracy. These calculations and the experiments with test planes to date, are believed to warrant the conclusion that for the test conditions in this laboratory, the disturbing effects are negligible for gap spacings up to at least 30 centimeters.

Should further work indicate the need for more complete corrections for ground planes, when the gap settings are large compared to the sphere diameter, such corrections will be a matter only of more extensive calculations.

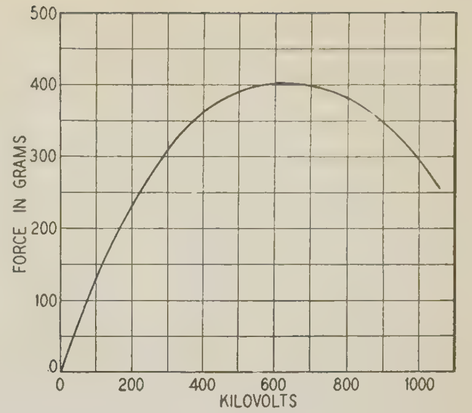


Fig. 9. Relation between force in grams and kilovolts with spheres set at Peek's values of sparking distances

RÉSUMÉ

Curve A of figure 4 has been drawn as a mean curve through the test points without the points being shown, because, when all the points were shown, they made the curve, at the scale drawn, look like a broad ragged line. This is due to the well-known erratic behavior of the sphere gap when used to measure voltage by the spark-over method. The deviations in the test carried out by the authors had the following range from curve A: at 20 centimeters spacing, from about 1 per cent below to 1 per cent above; at 40 centimeters spacing, from about 2 per cent below to 1 per cent above; at 60 centimeters spacing, from 6 per cent below to 2 per cent above; at 70 centimeters spacing, from 6.5 per cent below to 1 per cent above.

Table III—Computed Value of the Spacing Factor S

(Sir W. Thomson—"Papers on Electrostatics and Magnetism," p. 96)

Sphere Gap Setting—Cm	S	Sphere Gap Setting—Cm	S	Sphere Gap Setting—Cm	S
0	∞	35	0.11082	70	0.03863
5	1.13844	40	0.09174	75	0.03441
10	0.52852	45	0.07720	80	0.03084
15	0.32917	50	0.06592	85	0.02775
20	0.23159	55	0.05693	90	0.02509
25	0.17432	60	0.04963	95	0.02278
30	0.13696	65	0.04363	100	0.02075

It is interesting to note that curve A is practically coincident with the curve shown by Meador[5] in his figure 8.

Attention is directed to the form of the curve in figure 9 which shows that the maximum force between the spheres, when they are used as close as possible to spark-over voltage settings for the force measurements, occurs at a spacing of about 40 centimeters which is just the minimum spacing at which trouble from erratic sparking commences. Perhaps this is an indication that difficulties will be encountered if 100 centimeter spheres are used at spacings above this value for voltage measurements by the spark-over method.

The advantages of using force measurements

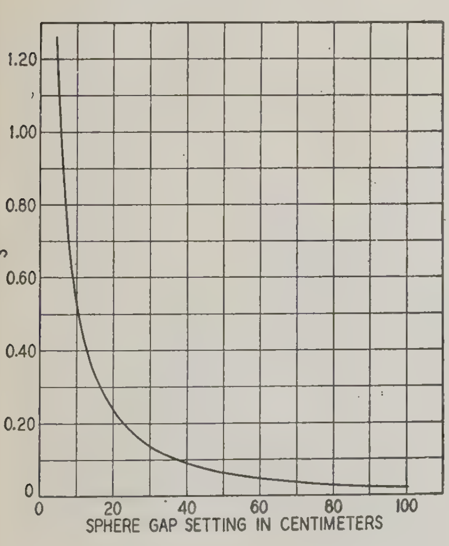


Fig. 8. Relation between sphere gap setting and the value of S used in the equation: $V = 9{,}405\sqrt{F/S}$

rather than spark-over distances for sphere gaps are:

1. No corrections are necessary for temperature, humidity, and barometric pressure, the only air characteristic of influence being the dielectric constant.

2. For any given spacing the relation between force and voltage may be calculated accurately from fundamental electrostatic theory without the use of any empirical data.

3. From (2) this method appears to have value as an absolute standard.

4. Adjacent bodies, floors, walls, etc., have at least no greater effect on force measurements than on spark gap measurements and their influence on force measurements is subject to exact calculation.

5. In making voltage tests on apparatus, the use of force measurements permits continuous voltage application and avoids the well-known difficulties incident to the spark gap method, not the least of which are the oscillations sometimes set up.

6. No series resistance is required if care is exercised to keep the spheres at all times separated far enough to avoid spark-over.

7. Less care is needed in making the spheres capable of withstanding spark-over and in maintaining a highly polished surface free from dust, lint, etc.

8. Absence of polarity effects, and effects due to the state of gap ionization.

9. Applicable to continuous potential, and to alternating potential of any frequency, without any change in the force-voltage relation.

10. Readings are always root mean square or effective values regardless of wave form.

The authors request the interest and co-operation of other laboratories in checking the results obtained for spheres in air and in extending this method of measurement to spheres of different diameter and to spheres mounted in dielectrics other than air, such as oil or other liquid dielectrics.

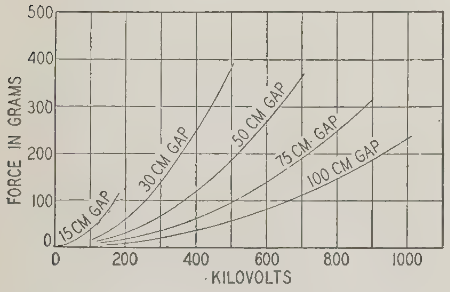


Fig. 10. Relation between force in grams tending to pull the spheres together and kilovolts (effective) for several gap settings (centimeters)

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Automatic Control for a Roughing Mill

Automatic screw-down equipment recently built for a 3-high roughing sheet bar mill represents one of the most recent advances in steel mill control equipment. This equipment, together with other control equipment designed for this mill and a semiautomatic screw-down control recently installed on another 3-high roughing mill, is described here.

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STEEL mill operators are analyzing production costs today more carefully than ever before and, as a result, are continually looking for improved labor saving devices as well as means for increasing production. In this search for improved equipment and methods electrical control is playing an increasingly important part. The object of this paper is to outline briefly some of the most recent designs in steel mill control equipment. Particularly, the operation, extreme flexibility, simplicity, and reliability obtainable from automatic screw-down controllers are emphasized. While the application of automatic screw-down controllers to sheet mills is described in this paper, it is worthy to note that this same type of controller may be readily adapted to practically any type of steel mill from large breakdown mills to almost any finishing mill.

In addition to the automatic screw-down controllers and other equipment developed specifically for a typical 3-high roughing sheet bar mill, a semiautomatic screw-down controller developed for another 3-high roughing mill also is described. These equipments are built for rugged steel mill duty and may be operated fully automatically, manually, or by using a combination of manual operations for the first few breakdown passes and fully automatic operation for the remaining passes.

Modern Roughing Sheet Bar Mill

A modern 3-high roughing sheet bar mill represents one of the most recent improvements in steel mill rolling practice. This clearly indicates the present

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* Application pending for re-election to grade of Member.

tendency toward more prevalent use of automatic magnetic control in the operation of steel mills. For the sake of simplicity, the description here will be confined to a 5-pass roughing mill schedule and will be based largely upon an equipment actually being installed in a steel plant. This mill, with its tables and control, embodies many special features which, based upon the judgment of the consulting engineers, were justified in order to operate the mill at a high sustained rate of production.

The 3-high roughing mill being installed in this plant, which has top and bottom rolls 52 inches wide and 33 inches in diameter and a middle roll 20 inches in diameter, operates at 29.3 rpm and is designed for roughing 12 inch bars in 5 passes to 15 or 16 gauge sheets. The first 2 passes will be rolled single thickness; then the sheets are matched, and the last 3 passes are rolled double thickness. Steel bars are fed to this roughing mill, shown in figure 1, by a single-width continuous furnace 100 feet long. An interesting feature of this new 3-high mill is the middle roll, which is balanced and is actuated up and down by the raising and lowering of the catcher's table.

Automatic Screw-Down Equipment

A special feature of this roughing mill is an automatic screw-down equipment. The screws are operated by 2 15-horsepower mill-type d-c motors, mechanically connected by a spline. On movements in the down direction, the motors are connected in series; on the upward movement of the screws, they are connected in parallel. A Clark 14-inch d-c series-wound high-speed-operating brake, with the inertia of its brake wheel reduced to a minimum, is mounted on each motor shaft.

The master switch, shown at the top of figure 2 and marked "manual-off-automatic" is, in normal operation, left in the "automatic" position. On the master panel the only items, besides the master switch, that have anything to do with the screw-down mechanism are the 4 buttons at the extreme right. The top button, which has a horizontal operating mechanism, is operated once for each pass; that is, as soon as the operator sees the end of the metal going through on pass 1, he momentarily presses this button which automatically sets up the mechanism for pass 2. After the metal has gone through pass 2, he again presses this same button and automatically sets up the mechanism for pass 3. No matter how long an operator holds down this button, it will not skip a pass but will move only to the next pass. The next to the top button is used to reset the screw-down mechanism, if it be found that the steel bars have to be taken off the table after making 1 or 2 passes, and the operator wishes to set up the mechanism again for pass 1.

This automatic screw-down equipment may be operated manually by simply moving the master switch handle to the "manual" position and then operating the 2 lower right-hand buttons. These 2 lower buttons provide inching in the manual operation but are inoperative when the master switch is in "automatic" position. One of these buttons is for down travel and the other for up travel. In manual operation, as long as the "down" button is depressed the screws will move downward, while pressing the other button moves the screws upward.

If the screw-down mechanism has been operated manually and it is desired to place the equipment again in position for automatic operation, all the operator need do is to inch the screw-down mechanism to pass 1 setting, return the master switch to "automatic" position, press the reset button; when the light for pass 1 shows up on the screw-down

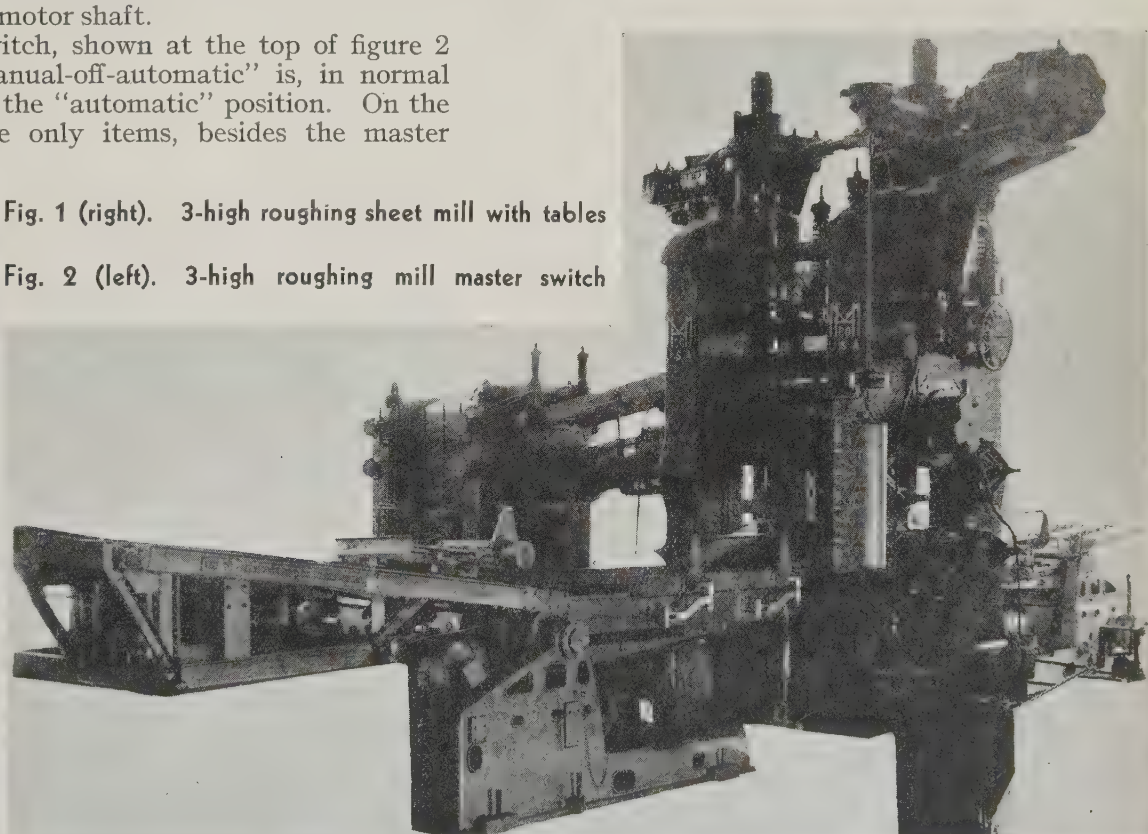


Fig. 1 (right). 3-high roughing sheet mill with tables

Fig. 2 (left). 3-high roughing mill master switch

position indicating device, the control is ready for automatic operation. The automatic screw-down control panel, shown in figure 3, is relatively simple considering that it handles 2 motors in series-parallel and provides reversing dynamic-braking duplex control.

In this installation, the screw-down limit switch is of the "preset" type, positively driven from the screw-down motors. The screw-down operation is made automatic for the various passes and, as mentioned before, the control is so arranged that the operator need only to press the top button to set the screw-down mechanism for each pass. Considering all the safety features on the screw-down mechanism and others in connection with the operation of the tables, it is expected that the mill's cycle of operation will be the fastest that could possibly be attained for this type of rolling. Particular attention was given to the speed on the upward movement of the screws after the completion of the last (fifth) pass, preparatory to entering a new bar in pass 1.

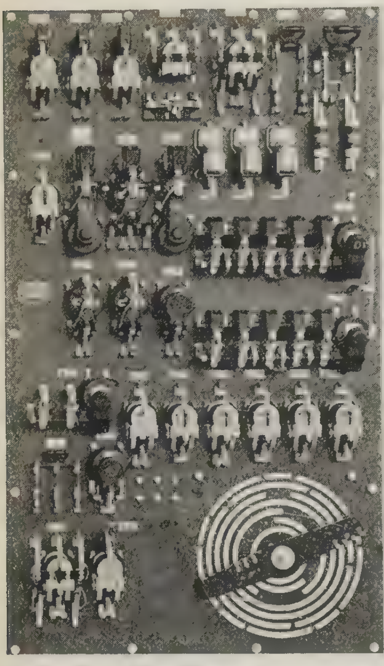
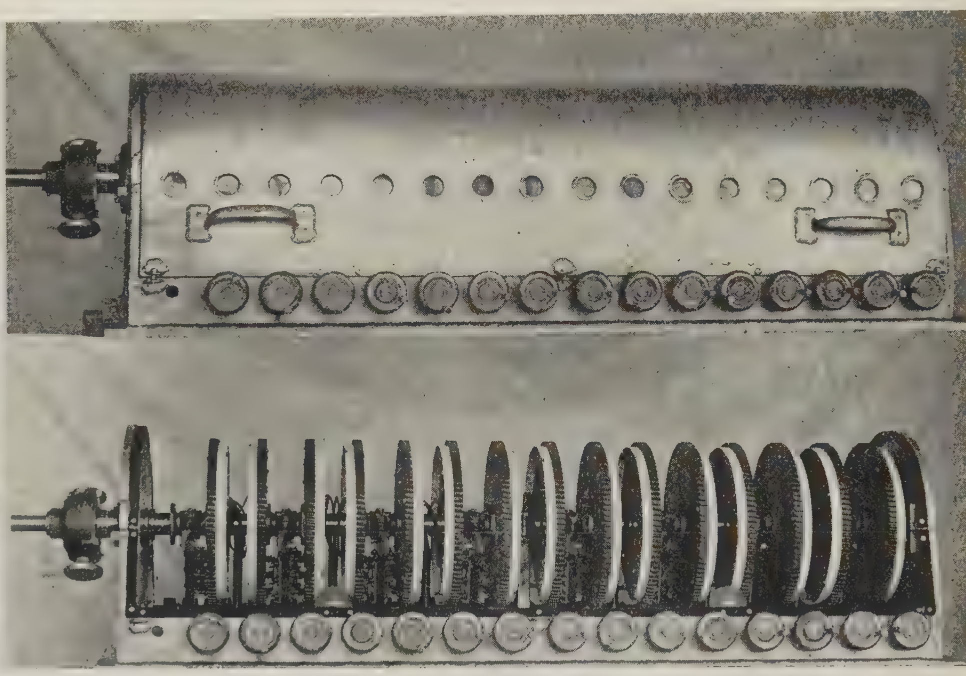


Fig. 3. Automatic screw-down control panel



Figs. 4 (top) and 5 (bottom). Exterior and interior views of the screw-down limit switch

The screw-down limit switch is mounted on the roller's side of the mill, immediately in front of the position occupied by the roller. This limit switch is similar in construction to that shown in figure 4, except that fewer dials are used since this is only a 5 pass mill, whereas with the switch shown in figure 4, a setup could be made for 15 passes. The switch is mounted on the mill housing with its long axis vertical, and the shaft extension is geared directly to the screw-down mechanism so that the motion of the limit switch shaft is in proportion to the motion of the screw-down mechanism itself.

The interior of the limit switch, shown in figure 5, is illuminated so that the scales inside the switch are visible through the portholes, which are small windows with clear celluloid panes. A stationary wire inside these windows makes it possible to read directly on the scales. The row of hand wheels below the scales determine the stopping position of the screw-down mechanism for each pass and give micrometer adjustment so that the stopping position for any pass may be varied at will. In making a setup, the individual handwheels are turned until the indicating scales read the desired positions for stopping for each pass. If some one pass must be altered after the setups are made for a given schedule, to make the correction it is merely necessary to turn the handwheel corresponding to that pass. When different sized rolls are installed, another handwheel, shown on the coupling end of the limit switch, is moved to make the necessary general correction for all passes. With this arrangement the calibration on the scales is not disturbed.

Figure 6 shows the screw-down position indicating device, which is mounted above the mill housing so that it can be seen from both sides of the mill. The lower lens (right-hand lens in figure 6) is red and is illuminated only while the screw-down motors are moving. The other 5 lenses are green and have numbers on them so that they read from top to bottom, "1, 2, 3, 4, and 5" (left to right in figure 6). For instance, when the screw is set for pass 3, the green lens showing number 3 is illuminated. In this way, on both sides of the mill, operators know at all times whether the screw-down mechanism is set and for what pass it is set.

This screw-down mechanism is extremely fast, gives very satisfactory stopping, and is, to the best of the author's knowledge, the simplest automatic screw-down equipment that has been placed on the market.

Roughing Mill Tables

Roughing mill tables, shown in figure 1, are another special feature of this 5-pass roughing sheet bar mill as a unit. The catcher's table is of the tilting type with manually operated magnetic control and 3 hand controlled stops. The control on the catcher's table is operated manually in preference to any automatic control by flag switch, photoelectric cell, or other mechanism, investigation having indicated that faster operation of this table could be obtained by manually operated control than by any other method.

The front table is stationary and carries 2 sets of chains: one is an ordinary set for feeding packs into the mill on passes 3 and 5; the other carries 2 dogs and a special safety stop each, for feeding the bars into the mill on pass 1. The front table is equipped with 3 stops, 2 of which are of the motor driven type operated with rotating magnet type motors, and the other is of the "knockdown" type. The motor operated stop nearest the mill is stationary relative to the mill, while the other is adjustable for different lengths in order to re-enter in the minimum time after delivery from pass 2. The knockdown stop, located farthest from the mill, is also adjustable in position for the minimum time in rematching the pair after delivery from pass 4. In entering the pair for both passes 2 and 4, the end of the pair hits the rotating stop next to the mill for front end matching. This stop then disappears, permitting the pack to enter.

The opening of the furnace door, the starting of the furnace chains, and the delivery of a pair of bars down a driven conveyor to the front table are tied in definitely and positively by electric control at some predetermined point in the cycle of 5 passes on the previous pair. The timing for the delivery of the second pair is such that, after the tail end of the preceding pair has left the rolls on pass 5 and the operator has pressed the button to set the mill for pass 1, the time between the release of the pack on pass 5 and the entry of the new bar on pass 1 will be the absolute minimum.

Fig. 6. Screw-down position indicating device; it is mounted vertically on the mill

Control of the screw-down mechanism, the preset arrangement for the various passes, the interlocking of the motor operated stops, and the delivery of the second pair of bars from the furnace are other most essential features in connection with the fast operation of the unit as a whole. Without proper interlocking of all of these factors, the unit never would be able to function within the time limits specified

There are many other interesting special features in the control arrangement. For instance, if the operator has the screw-down mechanism set for pass 5 (which is the last pass and therefore the lowest screw-down setting) and then tries to enter new bars, the reduction would be too great and roll breakage would be likely to occur. In order to prevent this, the control is so arranged that if the screw-down setting is not right for pass 1 when the bars get down to the front of the table, they will stop automatically and will not enter the mill until the screw is set for pass 1.

When the catcher table is tilted, it is impossible to run the chains on the roller side toward the mill. Therefore, it is impossible for a bar to be entered through the mill when the catcher table is in the "up" position, as this would permit the bars to come through under the catcher's table. This same interlocking system also prevents the entering of bars between the top roll and the middle roll at the same time that bars are going between the bottom roll and the middle roll. Whenever this occurred in the past, roll breakage was almost sure to follow.

Fig. 7. Semi-automatic screw-down control pane

With this control system, the bars are delivered automatically from the furnace and are deposited automatically on the roller's table, ready to enter the mill as soon as the screw-down mechanism has been set for pass 1 after the end of the preceding pack has gone through. This entire control system is provided with adequate protective measures so as to prevent any mishap from an error on the part of the operator. For instance, if by any chance the operator has not pushed the button to set the rolls for pass 1, the bars will be carried up to within 15 inches of the mill and there they automatically stop. The bars will remain in this position until the operator

has pressed the button, but even then they cannot enter the mill until the rolls have reached the predetermined opening for pass 1. When the pack goes through on pass 5 the time elapsing until the new bars on pass 1 are entered, is much shorter than anything that has been accomplished previously on this type of mill. It is claimed that this particular unit should and will be the fastest operating roughing sheet bar mill of its kind that has ever been built.

Semiautomatic Screw-Down Control

Another type of screw-down controller, shown in figure 7 and recently installed on a 3-high roughing mill, is intended primarily for semiautomatic operation; it is made as simple as possible both in equipment used and in change-overs necessary from one schedule to another. This controller was designed for a maximum of 7 passes and is operated entirely from 2 foot switches, one of which is shown in figure 8. One of these is pressed for the up motion and the other for the down motion. The screw-down limit switch is mounted on the left hand side of the mill housing, within easy reach of the operator so that changes in any pass setting may be made readily by the operator.

This 7-pass screw-down control equipment consists of 1 entering, 1 matching, and 5 down motion passes. The down motion passes are arranged so

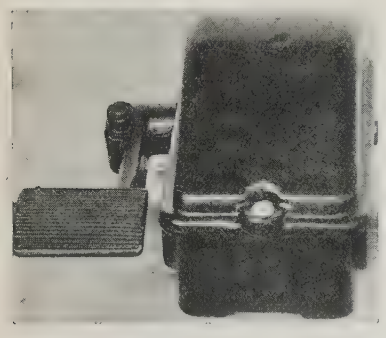


Fig. 8. Foot operated switch for semiautomatic control

that the first time the down foot switch is depressed, the screw-down limit switch will move to the setting corresponding to the first dial of the down travel. The next time it will go to the second setting, and then to the next, and so on. In one complete mill cycle, regardless of the number of passes, or where matching takes place, there are only 2 times in the cycle when the screw-down motors go up. The first time is when the matching takes place and the next time is when the pair of bars have been finished and the screws go up to prepare for the entrance of the next pair of bars. Therefore, on the screw-down limit switch there are 5 dials for the down travel and only 2 dials for the up travel.

In making a setup for the up travel, the first dial is adjusted for the matching pass and the second dial for the entering pass. This second dial limit switch mechanism stops the screw-down in its up travel after all other passes are finished. Therefore, regardless of the position of the screw-down mechanism, the first time in the cycle that the "up" foot switch is depressed the mechanism will go up to the matched setting. The next time in the cycle that the "up" foot switch is depressed, it will go to the first pass setting, thus making the screw-down setup ready for new bars to be entered. The next time this same foot switch is depressed it will go to the matched setting, and so on.

The screw-down position indicating device, likewise, has 5 numbered lenses for the down motions, and 2 lenses for the up travel. The up motion lenses are marked *M* and *E*, corresponding to matching and entering passes.

Since this control equipment was designed for semiautomatic operation of the mill, it permits any desired variations in the rolling practice. For instance, if after the third pass the operator presses the "up" foot switch, this motion automatically cancels all setups in the down direction so that the mill is ready to start with the first down setting, and so on. In this way any number of passes up to 7 may be had, and matching may take place on any pass and on either side of the mill that the operator desires. In changing over from one schedule to another it is only necessary for the operator to reset the dials to the proper positions, no operation of any transfer devices being necessary. Simplicity of operation may be shown best by outlining a typical sheet bar rolling cycle.

Suppose that a 5-pass schedule is being rolled with matching taking place on the roller's side of the mill after the second pass. It is assumed that the screws are set properly for the first pass. On the first and second passes the bars go through the rolls one after the other. After the rear end of the second bar has gone through on the first pass, the "down" foot switch is depressed momentarily. The 2 bars now are brought back through the second pass; after the rear end of the second bar has gone through, the operator momentarily presses the "up" foot switch, causing the screw-down mechanism to move up to the proper setting for the matched pair. After the steel has gone through on the matched pass the "down" foot switch again is depressed momentarily, causing the setup to be made for the fourth pass. When the match sheets have gone through the fourth pass, the operator again presses the "down" foot switch and the screws move down for the fifth and final pass. After the rear end of the sheets goes through the final pass, the "up" foot switch again is depressed momentarily and the screws move up to the proper setting for the entrance of new bars.

With all the variations possible in the methods of operation, this system is not restricted to any particular pass for matching or to any particular number of passes. It seems to be an ideal setup for many types of roughing mills. Of course, it must be realized that in this type of semiautomatic control arrangement the operator must press the "down" foot switch when the screws should come down and the "up" foot switch when the screws should go up; the whole system outlined here for this mill control is based upon the assumption that the operator is sufficiently intelligent to do this. The screw-down indicating device shows, each time, exactly for which pass the screws are set.

Transients in the Finite Artificial Line

Some of the results obtained and the conclusions reached in a study of the current at the end of any section of a nondissipative artificial line terminated at one end at midseries position by a physically realizable resistance and excited at the other end at midseries position by a unit continuous voltage are presented briefly herewith. This paper is a condensed version of a longer paper* on file in the Engineering Societies Library.

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IN SO FAR as their general operational formulation is concerned, the disturbing effects of terminal impedances in the transient response of the periodic artificial line to voltages suddenly applied at one end already have been treated.[1] However, even with the simplest terminations, the difficulty of determining useful explicit or time solutions of the complicated operational expressions formulating these disturbing effects is such that it has led investigators either to avoid these terminal effects entirely or to reduce them to relatively simple forms by the use of simplifying assumptions all of which are included as either special or limiting cases of the following ideal problem: The line is assumed to be terminated in impedances that for all frequencies exactly simulate, within fixed constants, its characteristic impedance as seen from both ends.[1,2] Such exactly simulating impedances, however, are not physically realizable;** moreover, the limiting cases of this assumption, such as the cases of open or short-circuited far end,[3] do not represent the manner in which the artificial line usually is terminated when used as a low-pass wave filter. It is evident, therefore, that previous studies of the finite artificial line in the transient state have been confined to either impractical or unrealizable terminal impedances.

It is the purpose of this paper to present a few curves and conclusions arrived at in a study of the current at the end of any section of a nondissipative artificial line of n sections when terminated at one end at midseries position by a physically realizable resistance $R = k\sqrt{L/C}$ and excited at the other end

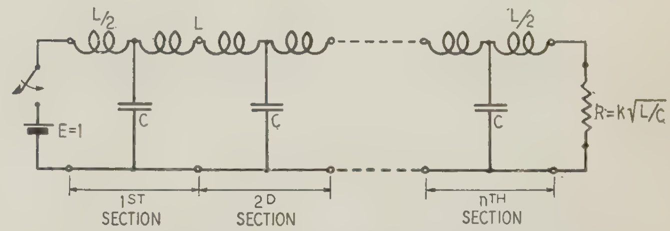
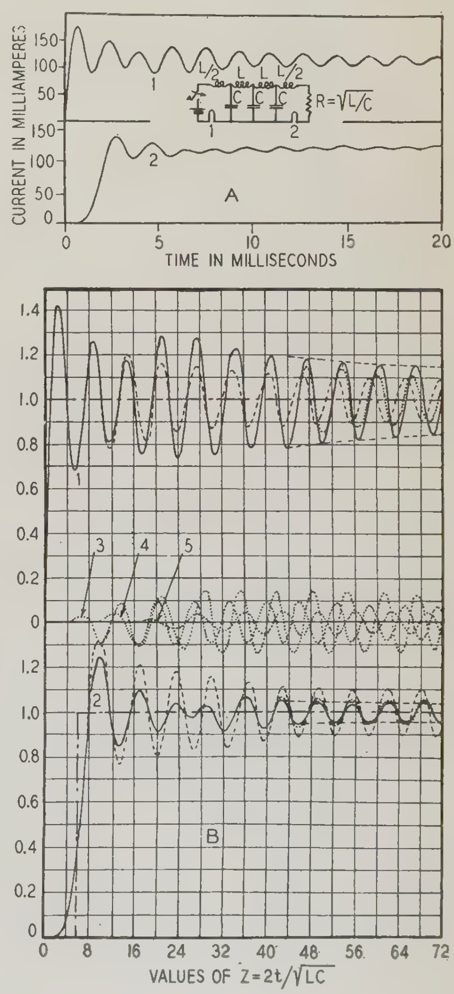


Fig. 1. Diagram of a nondissipative artificial line terminated into a resistance $R = k\sqrt{L/C}$

at midseries position by a unit continuous voltage applied at the time $t = 0$ (see figure 1). The solution of this problem is of importance in the study of the finite low-pass filter, and in establishing the relation between the response of the finite artificial line and that of the corresponding finite smooth line. (By the corresponding smooth line is meant here

Fig. 2. Indicial admittance of initial (1) and last (2) mesh for a line of 3 sections

Tracing of oscillogram (right)



——— Current in finite line as computed by means of expansion theorem

..... Current in finite line as computed by means of series treatment. Curve 4 is the first reflection in the initial mesh; curves 3 and 5 are the first and second reflections in last mesh

– – – – – Current in corresponding mesh of infinite line

–·–·– Current in corresponding smooth line

Note: Multiply ordinates by $\sqrt{C/L}$

* A condensed version of a longer paper, now on file at the Engineering Societies Library, 33 West 39th Street, New York, N. Y., which is based almost entirely upon material developed in a thesis "Transient Oscillations in Low Pass Electric Wave Filters of a Finite Number of Sections" by M. J. Di Toro, Brooklyn Polytechnic Institute, June 1933; recommended for publication by the A.I.E.E. committee on communication. Manuscript submitted Oct. 25, 1933; released for publication Nov. 26, 1934.

** The authors are indebted to Drs. J. R. Carson and O. J. Zobel of the American Telephone and Telegraph Company for calling their attention to the physical possibility of closely simulating the characteristic impedances of the usual lumped lines used as wave filters. See the section on the simulation of wave filter impedances in the paper "Extensions to the Theory and Design of Wave Filters" by O. J. Zobel, Bell System Technical Journal, April 1931, v. 10.

1. For numbered references see list at end of paper.

that line that has the parameters L and C uniformly distributed per "unit length." The magnitude of this "unit length" depends, of course, upon the degree of approximation desired between lumped and smooth lines.) In addition, the solution is also, to a first approximation, a solution for the periodically loaded cable with a termination often used in practice. The nondissipative line considered here is, of course, ideal; the solution described here, however, is nevertheless important because the disturbing effects, which arise because of the impedance mismatch existing at the far end of the line, are brought out to the greatest extent and in the clearest manner when damping caused by dissipation is avoided.

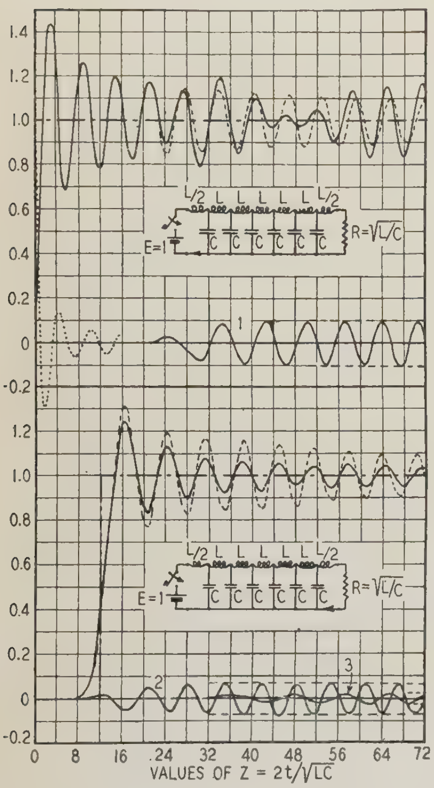


Fig. 3. Indicial admittance of initial (upper curves) and last (lower curves) mesh for a line of 6 sections

—— Current in finite line as computed by means of the series treatment. Curve 1 is the first reflection in the initial mesh; curves 2 and 3 are the first and second reflections in last mesh

----- Current in corresponding mesh of infinite line

-·-·- Current in corresponding smooth line

..... Fictitious voltage causing first and second reflections

Note: Multiply ordinates by $\sqrt{C/L}$

For a line of not more than 3 sections, the conversion of the operational expressions of the problem into explicit or time functions was effected by the use of the expansion theorem of Heaviside. The enormous increase in complexity inherent in the use of this theorem for an increasing number of sections was avoided, however, by the use of an approximate but powerful series treatment which broke up the solution into a series of "apparent reflections." Figure 2 shows the current in a line of 3 sections, for $k = 1$, as obtained by means of the expansion theorem and by the approximate series treatment. Figures 3 and 4 show, respectively, the current in a line of 6 sections for $k = 1$ and the current in a line of 3 sections for $k = 1/2$ and $4/5$ as obtained by the series treatment. The corresponding oscillograms shown with the theoretically computed curves were obtained by the use of an artificial line especially designed and constructed to give a large time scale rendering it possible to employ a string type oscillograph with maximum film speed. The parameters of this line were: $L = 0.288$ henry per section (coil resistance = 30 ohms per section); $C = 1$ microfarad per section.

The conclusions reached in the longer paper (see footnote at beginning of this paper) are:

1. Unlike the indicial admittance of the corresponding nondissipative finite smooth line with the same termination, the transfer indicial admittance of the h section of the circuit shown in figure 1 for $k = 1$ differs from the indicial admittance of the h section of the corresponding line with an infinite number of sections, or the line assumed terminated into its characteristic impedance, by the presence of modulated oscillations caused by a series of complicated superimposed terms. (In accordance with their standardized definition, the words "modulated oscillations" are used here to denote the result produced by the superposition of oscillatory curves of different frequencies.) These superimposed terms have a virtual or apparent velocity of propagation of $1/\sqrt{LC}$ sections per second and for this reason may be called virtual or apparent reflections. The first and second apparent reflections, which produce the greatest disturbance relative to that of the succeeding reflections, become of maximum amplitudes $0.18\sqrt{C/L}/\sqrt{2n-h}$ and $0.18\sqrt{C/L}/\sqrt{2n+h}$ in the vicinity of the arguments $z = 2t/\sqrt{LC} = 7(2n-h)$ and $7(2n+h)$, respectively. All the apparent reflections can be considered physically as the response in the $2n-h$, $2n+h$, etc., sections of the corresponding line with an infinite number of sections to fictitious voltages suddenly applied at midseries position to the initial section. The fictitious voltage causing the first and second apparent reflections is shown in figure 3.

2. For values of R such that k takes on values other than 1, the transfer indicial admittance of the h section of the circuit shown in figure 1 can be considered as composed of the transfer indicial admittance of the h section of the corresponding line with an infinite number of sections plus a series of apparent reflections having a virtual or apparent velocity of propagation of $1/\sqrt{LC}$ sections per second. These reflections oscillate about and ultimately coincide with

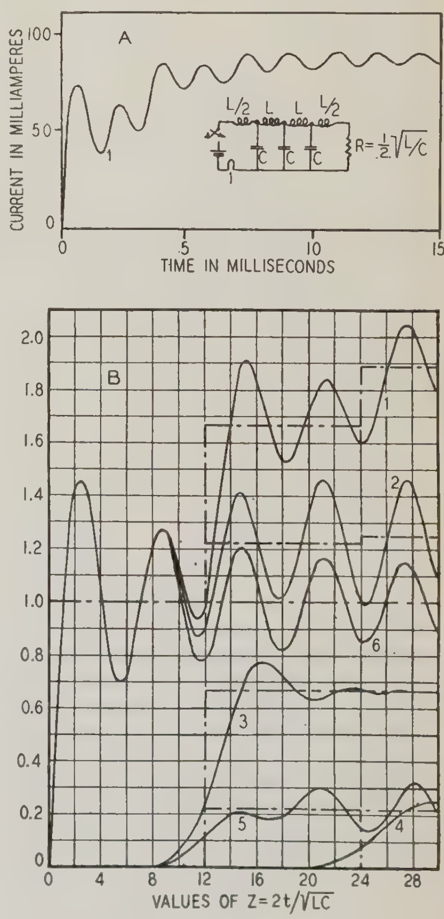
Fig. 4. Indicial admittance of initial mesh for a line of 3 sections terminated into the resistances $R = (1/2)\sqrt{L/C}$ (curve 1) and $R = (4/5)\sqrt{L/C}$ (curve 2) as computed by means of series treatment

Tracing of oscillogram (top)

—— Curves 3 and 4 are the first and second reflections for k = 1/2; curve 5 is the first reflection for k = 4/5; curve 6 is the current in initial mesh of infinite line

-·-·-. Current in corresponding line with same terminations

Note: Multiply ordinates by $\sqrt{C/L}$



the corresponding known reflections of the finite nondissipative smooth line with the same terminations.

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An Electronic Regulator for an Alternator

An automatic voltage regulator for an alternator consists essentially of a voltage sensitive element which controls, through suitable apparatus, the excitation of an alternator. In the voltage regulator described herein, the voltage sensitive element is a nonlinear bridge circuit. Its output controls, through a phase shifting circuit, a grid-controlled mercury-vapor tube, the output of which is fed into the field circuit of the alternator. The phase shifting circuit employs a fixed condenser and a variable resistance, the latter being obtained from 2 3-electrode vacuum tubes whose grids are controlled by the nonlinear bridge circuit. The regulator is rugged in construction and at constant frequency provides close regulation without apparent hunting or voltage distortion.

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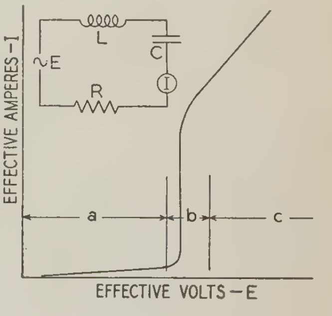
THE increasing need for an automatic voltage regulator to meet the exacting requirements of industrial service has led to innumerable attempts to produce a device which will keep the terminal voltage of an alternator constant as the load is varied. If an alternator has its field current adjusted so as to supply rated voltage at no-load and rated frequency, the terminal voltage decreases as resistive or inductive load (the usual types of load) is applied to the machine. This condition is undesirable and the problem is to maintain automatically a constant terminal voltage regardless of the load on the machine. In order to accomplish this the generated voltage of the machine must be controlled to compensate the variable impedance drop and the variable demagnetization effects.

Many regulators have been built which will, in general, accomplish these results; but, considerable improvement in this field is still possible. The main faults encountered in the ordinary type of vibrating contact voltage regulator are: (*a*) its relatively slow pulsating action; and, (*b*) the wear and tear and the necessary readjustments of its moving parts.

The recent improvements which have been made in electronic tubes have provided the basis for many successful experiments on controlling and regulating mechanisms for various types of apparatus and circuits. The grid-controlled mercury-vapor tube, in particular, is being extensively applied to control circuits. The regulator described in this paper uses such a mercury vapor tube in conjunction with its control circuit and voltage sensitive circuit to vary the average field current of the alternator, as a means of controlling the effective field strength without the use of auxiliary windings or other devices on the alternator.

Fig. 1. Volt-ampere characteristic of the nonlinear bridge circuit of the alternator voltage regulator



This paper presents the explanation of the electronic voltage regulator in 4 parts:

1. The voltage sensitive element of the regulator: the nonlinear bridge circuit.
2. The control circuit of the mercury vapor tube.
3. The operation of the regulator.
4. Typical test data of the alternator with the regulator.

The Voltage Sensitive Element

In attempting to develop an electronic tube voltage regulator, a nonlinear bridge circuit[1] offered most interesting possibilities as the voltage sensitive element of the regulator circuit. A simple series circuit consisting of resistance, capacitance, and a saturable iron core reactor, forms the basic element of such a nonlinear bridge circuit. The effective voltampere

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1. For all numbered references, see list at end of paper.

characteristic of such a circuit is shown in figure 1. The region marked *a* on the figure is associated with the unsaturated condition of the iron core reactor; region *c* is associated with the saturated condition; and, in region *b* the circuit conditions become unstable and the current rises very rapidly. The value of the voltage at which this rise in current takes place is a characteristic of the circuit which is called the "critical voltage." (Detailed investigation of the phenomena in the unstable region is being carried on at The Polytechnic Institute of Brooklyn by Prof. E. Weber.)

Two series circuits each having characteristics of the type shown in figure 1 may be combined to produce a voltage sensitive, nonlinear bridge circuit as shown in figure 2. The output voltage E_0 is the difference in voltage drops across the 2 condensers. If the 2 capacitances are practically equal, the output voltage will be large when the current through one condenser is very much larger than the current through the other. This condition will exist when one arm of the bridge is operating in its unstable region. For the 2 cases when neither arm operates in its unstable region, or when both arms operate in their unstable regions, the output voltage will be very small. If both arms are identical, their characteristics are identical and the output voltage will be zero for all values of applied voltage.

Consider the case of a nonlinear bridge circuit in which $R_1 = R_2$, $C_1 = C_2$, and the reactors are similar except for a slight difference in their number of turns. The 2 arms will have slightly different critical voltages, so that for values of applied voltage E between zero and the lower critical voltage, the output voltage E_0 will be practically zero, but when one arm of the bridge circuit becomes unstable, the voltage output will rise very rapidly. As the applied voltage is increased still further, the second arm becomes unstable with the result that the output voltage again becomes small. It remains small for all higher values of applied voltage. The output voltage E_0

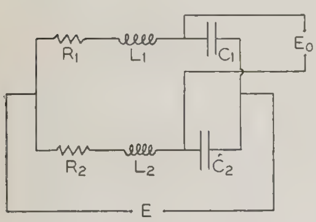


Fig. 2. Nonlinear bridge circuit of the regulator

E is the applied voltage of the bridge circuit

E_0 is the output voltage of the bridge circuit

will have slight irregularity for voltages above and below the critical values, since it is practically impossible to obtain identical magnetic characteristics for the 2 reactors. This condition is further influenced by the fact that the characteristic of the nonlinear bridge for increasing values of applied voltage may differ slightly from that for decreasing values of applied voltage, the difference depending upon the relative values of resistance R and capacitance C.

In addition to the critical voltage characteristic of the nonlinear circuit, there are phase angle changes which occur in between the regions *a* and *c* on figure 1; were it not for the changes in wave shape which also occur within this region it might be possible to make use of this phase shift to control the grid of the mercury vapor tube directly.

From the experimental work on nonlinear bridge circuits, it is found that the critical voltage depends predominantly upon the characteristics of the reactors in the circuits. The value of the output voltage after one arm of the bridge circuit comes into its unstable region is some function of the capacitance and resistance. As either the resistance or capacitance is decreased, the output voltage increases. A typical characteristic of one test on the nonlinear bridge circuit is shown in figure 3. It might appear at first glance that the output voltage could be increased to any desired value by decreasing the resistance of the circuit. This, however, is not true if the circuit characteristic is to be the same for increasing and decreasing values of applied voltage E. There is a particular combination of resistance and capacitance for which the output voltage E_0 is a maximum and for which the same characteristic results for both increasing and decreasing values of applied voltage. Any change of resistance or capacitance above these

E_0 is the output voltage
R_1 = 75 ohms
R_2 = 58 ohms
C_1 = 12 microfarads
C_2 = 10 microfarads
L_1 = No. 2,334, 110 volts
L_2 = Same, 10 volts, 8 volt Viking coil

Curve "a" is for increasing values of applied voltage

Curve "b" is for decreasing values of applied voltage

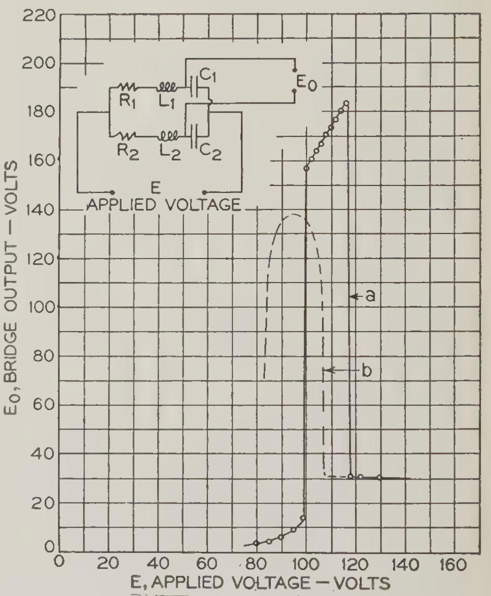


Fig. 3. Nonlinear bridge characteristics

values, while still producing a unique characteristic, renders a lower value of output voltage; and, any decrease in resistance or capacitance causes the characteristic to become double valued and the output voltage greater.

The characteristic of the nonlinear bridge circuit used in this regulator is shown in figure 4. From this it can be seen that if the bridge is connected directly across the alternator terminals, any attempt of the machine to increase its terminal voltage above its rated value of 118 volts results in a greatly magnified increase of output voltage from the bridge circuit. This condition is the foundation upon which the operation of the regulator circuit depends. The field current of the machine is initially adjusted so that at full load its terminal voltage is a little above

its rated value. Any decrease in load tends to increase the terminal voltage. The greatly increased output voltage from the bridge circuit, caused by this tendency, is made to operate a circuit which in turn regulates the average field current of the alternator and thus controls the terminal voltage. Having designed the voltage sensitive element of the regulator, a control circuit which would respond to these changes in the output voltage of the bridge was then developed.

Control Circuit of the Mercury Vapor Tube

As a relatively large and variable amount of direct current is required to produce the variation in the average alternator field current needed to maintain constant terminal voltage over a wide range of load, a mercury vapor tube (General Electric Company type *FG*-27) was selected as the current carrying element.

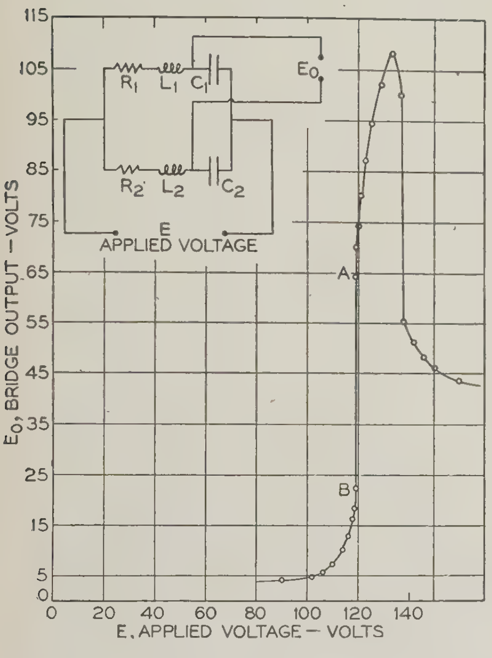


Fig. 4. Nonlinear bridge characteristic

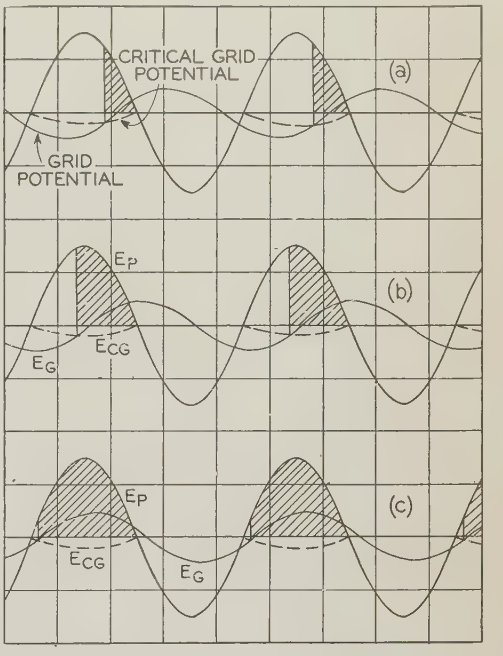
E_0 is the output voltage
R_1 = 78 ohms
R_2 = 62 ohms
C_1 = 27.4 microfarads
C_2 = 20.0 microfarads
L_1 = No. 2,334, 110 volts
L_2 = Same, 10 volts, 8 volt Viking coil

This curve is followed for increasing and decreasing values of applied voltage

Any one of several methods can be used to control the average current passed by the mercury vapor tube; but, in this particular case, since the grid and anode are supplied by a-c voltages, the phase shifting method[2] seemed best. By this method, the average value of current passed by the mercury vapor tube can be controlled from zero to full value by shifting the phase of the grid voltage with respect to the anode voltage. Whenever the grid potential becomes less negative than a certain value, known as the "critical grid voltage," the tube begins to pass current and continues to pass current until the anode potential becomes zero. The basic principle of the grid phase-shifting method of control is illustrated in figure 5. The shift of phase of the grid potential with respect to the anode potential can be secured by the use of a circuit having the principles of that shown in figure 6. From the vector diagram of this phase shifting circuit it can be seen that, as the value of R changes, the angle θ between the grid potential E_g and anode potential E_a changes. When $R = 0$, $\theta = 180$ degrees, and when $R = \infty$, $\theta = 0$.

In order to employ this circuit in an automatic voltage regulator, it is necessary to secure a resistance for the variable arm R of the phase shifting circuit which will change from a relatively low value to an almost infinite value in response to the variable voltage E_0 from the nonlinear bridge circuit. Since this bridge circuit can supply no appreciable power output, the plate resistance of a 3 electrode, high vacuum type, electronic tube can be used as the variable resistance arm R. If this tube has its grid negatively charged during the time its plate is positive, the effective resistance of the tube can be increased from a relatively low value to an almost infinite value by further increasing the value of the negative charge on the grid. This principle is used in this regulator for utilizing the variable output voltage E_0 from the bridge circuit to provide the variable resistance for the phase shifting circuit of the mercury vapor tube. Two tubes, type 10, are arranged for 2-way rectification and are connected so that the grids are negatively charged from the output of the bridge circuit during the half cycles when the respective plates are positive. The values of anode potential and negative grid potential on these tubes are such that when one arm of the nonlinear bridge circuit operates in its unstable region (high output voltage), the negatively charged grid completely prevents the passage of current between anode and cathode; and, when the tubes pass their maximum current, their apparent or effective resistance is relatively low.

Fig. 5. Phase shifting diagrams



The maximum anode potential of these tubes is 470 volts. In order to secure cut-off at this voltage, a value of −62 volts is needed on the grids. The output voltage from the nonlinear bridge is capable of supplying up to −85 volts without an appreciable

change in applied (terminal) voltage. Thus, an almost infinite value of resistance is secured when the output voltage from the bridge circuit is high. This action serves to put the grid voltage practically in phase with the anode voltage and causes the mercury vapor tube to pass its maximum value of current. When the output voltage of the bridge circuit is low, the tubes pass a maximum current of approxi-

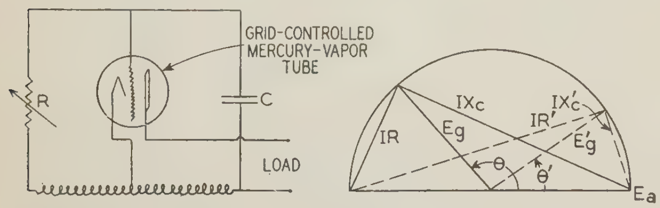


Fig. 6. Phase control diagrams, showing schematic diagram (left) and vector diagram (right)

mately 5 milliamperes. Calculation and test both show that, in order for the capacitance voltage drop to be large enough to shift the grid voltage through a large angle, a condenser of 0.04 microfarad is most satisfactory. Thus, when the output voltage from the bridge circuit is low, the angle between the grid and anode potentials is nearly 180 degrees and the current passed by the mercury vapor tube is a minimum. The circuit diagram of the complete regulator is shown in figure 7.

Operation of the Regulator

The critical voltage of the nonlinear bridge is the rated terminal voltage of the alternator. Therefore, the output voltage of the bridge circuit is along the line AB of the nonlinear bridge characteristic, figure 4. This output voltage will be high when the terminal voltage is a very small amount greater than the critical voltage; and, it will be small when the terminal voltage is very slightly less than the same critical voltage. The total change in terminal voltage required to produce the full useful change in the bridge output voltage is so small as to be unobservable on an ordinary voltmeter. The field rheostat of the alternator is set so that at full load on the machine, and with the regulator disconnected, the terminal voltage is several volts above rated value. The output circuit of the mercury vapor tube is connected to the field circuit of the alternator in such a manner that, as the tube current increases, the field current is decreased. In order to protect the mercury vapor tube from an overload current which would be caused by the field rheostat being cut out too far, it might be desirable to connect the output of the mercury vapor tube across a fixed resistance in series with the field rheostat, instead of directly across the field rheostat. If this is not done a stop should be provided on the field rheostat to prevent it being cut out beyond a certain limit. Instead of connecting the mercury vapor tube so as to control the main field current of the alternator, its output may be fed into an auxiliary field winding to produce the same result. The regulator receives its power from any one phase of the alternator under regulation and this source constitutes the only power supply necessary.

While the cathode of the mercury vapor tube is being heated, the output voltage from the bridge circuit is high, since the terminal voltage of the machine is above the critical voltage of the bridge. This serves to shut off the 2 tubes constituting the variable resistance in the grid phase shifting circuit of the mercury vapor tube. The nearly infinite resistance of these 2 tubes (see vector diagram in figure 6) causes the grid voltage of the mercury vapor tube to be in phase with the anode potential as soon as the plate circuit is completed through the field rheostat and causes the mercury vapor tube to pass its maximum current instantaneously. This action reduces the average field current of the alternator and thus reduces the generated electromotive force and terminal voltage—a process which will continue until a balance is reached somewhere between A and B (see figure 4) with the terminal voltage at its rated value. A rise in the bridge output voltage increases the current in the mercury vapor tube and overcomes the tendency of the machine to increase its terminal voltage; and, conversely, a fall in the bridge output voltage reduces the mercury vapor tube current to practically zero and the machine thereby tends to increase its voltage. The

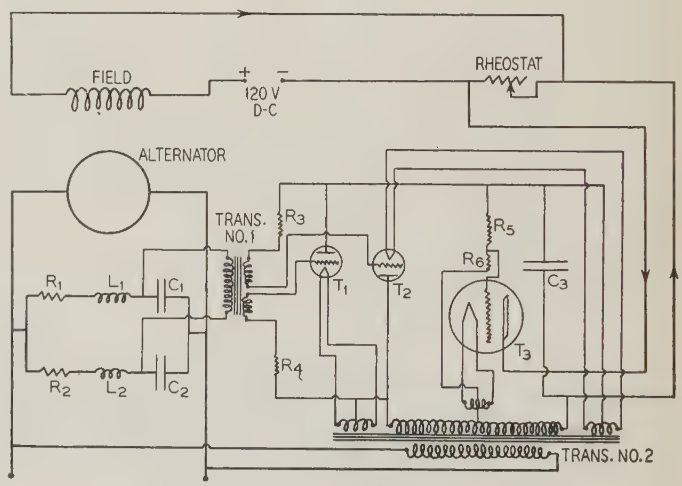


Fig. 7. Diagram of connections

R_1 = 78 ohms; R_2 = 62 ohms; R_3 = R_4 = 500,000 ohms; R_5 = 1 megohm; R_6 = 0.1 megohm
C_1 = 27.4 microfarads; C_2 = 20.0 microfarads; C_3 = 0.04 microfarad
T_1 and T_2 are 3 electrode vacuum tubes, type 10
T_3 is a grid-controlled mercury-vapor tube
Transformer number 1—70 volt primary coil (5,000 ohms impedance) 2 70 volt secondaries (5,000 ohms impedance)
Transformer number 2—120 volt primary coil; 330 volt secondary coil (center tapped); 2 7.5 volt secondaries (center tapped); 5 volt secondary coil (center tapped)

slightest tendency of the alternator to change its terminal voltage disturbs the balance of the very sensitive nonlinear bridge circuit. The resultant change in the output voltage of the bridge circuit varies the effective resistance of the variable arm of the phase shifting circuit which changes the current in the mercury vapor tube in such a way as to main-

tain a practically constant terminal voltage at all loads.

Test Data of Alternator and Regulator

Tests made on a 12 kw alternator show conclusively the ability of the regulator to maintain constant terminal voltage while the load is varied from no-load to more than full load. The data of one of these tests are plotted and shown in figure 8.

Without the regulator in operation the voltage regulation of the alternator is $\frac{20}{118.5} \times 100$ per cent $= 16.9$ per cent. With the regulator in operation the total change in terminal voltage from no-load to full load is 0.2 volt. The voltage regulation is, therefore, 0.17 per cent. This regulation was obtained at 60 cycles, and although as yet no tests have been made at other constant frequencies, it is quite likely that with suitable circuit adjustments this sensitivity can be maintained at other frequencies somewhat above and below 60 cycles; the effect of varying frequency is to vary the voltage at which the circuit regulates.

The close regulation at constant frequency is due to the extreme sensitivity of the non-linear bridge circuit. To the knowledge of the authors this control system has never before been applied in this manner as a voltage regulator for alternators.

Summary of Advantages

With the regulator in operation on a 12 kw alternator, the terminal voltage is maintained with a regulation of 0.2 per cent as compared to the regulation of 17 per cent without the regulator. Closer regulation than 0.2 per cent is not maintained in present practice by ordinary voltage regulators for alternators. The commercial electronic tube voltage regulators, which have been developed for regulation of this order of magnitude, are relatively costly and complicated devices, generally requiring the use of some standard source of voltage as a datum for comparison. The electronic voltage regulator which has been explained in this paper is relatively inexpensive and it neither requires the use of any standard datum voltage nor the use of any power source other than that of the alternator under regulation.

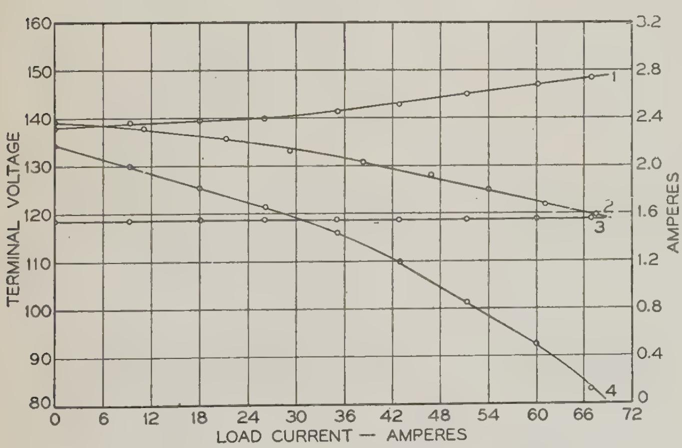


Fig. 8. Test with regulator in operation

1. The variation of field current (right-hand scale) caused by the regulator
2. The variation of terminal voltage (left-hand scale) without the regulator
3. The variation of terminal voltage (left-hand scale) with the regulator
4. The variation of plate current (right-hand scale) in the mercury vapor tube

The regulator has no parts requiring frequent adjustment or replacement; and it is adaptable to any alternator if the proper provision is made for current carrying capacities in the regulator parts. The action of the regulator is practically instantaneous and it is free from noticeable hunting or undesirable transient conditions. An oscillographic investigation of the conditions existing at the alternator terminals and of conditions existing in the field system reveals the following facts:

1. That the field current of the alternator is apparently as pure a d-c current with the regulator in operation as it is without the regulator.

2. That the regulating action of the regulator apparently does not appreciably distort the voltage wave form of the alternator.

The advantages of this electronic voltage regulator over many of those now in use are summarized as follows:

1. The regulator has no moving parts which require frequent adjustment or replacement.

2. The regulator is noiseless in operation.

3. It is readily applied to any alternator by the use of a single transformer to adapt the critical voltage of the bridge circuit to the rated voltage of the machine.

4. It provides close regulation without noticeable hunting, and its action is practically instantaneous and free from disturbing transient conditions.

5. The regulator does not require the use of any auxiliary windings or devices on the alternator, since its controlling action is obtained by varying the voltage drop across the field rheostat.

6. This regulator does not require any source of power other than that of the alternator under regulation and it does not need batteries or standard voltages for use as a datum for comparison.

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News
Of Institute and Related Activities

The Summer Convention This Month at Cornell University

THE fifty-first annual summer convention of the Institute, which will be held on the campus of Cornell University, Ithaca, N. Y., June 24–28, 1935, promises to be an outstanding affair. The summer convention committee, under the chairmanship of R. F. Chamberlain, has arranged an excellent program combining sports, recreation, and social functions with an enlarged technical program consisting of 10 sessions and in addition a number of informal technical conferences. The splendid facilities which the university affords have made it possible to offer members and guests these features at a very reasonable cost, and a large attendance is anticipated. Headquarters will be in Willard Straight Hall.

Entertainment Features for Women

The entertainment features scheduled for the convention were outlined briefly in the announcement in the May 1935 issue of Electrical Engineering, page 563. In addition to the features mentioned therein, of interest particularly to women, several others are being arranged. The features for women's entertainment may be summarized as follows:

On Monday morning, June 24, following the annual business meeting, there will be a tour of Myron Taylor Hall and other campus buildings in the vicinity of Willard Straight Hall. In the afternoon there will be a tea in the reception room of Balch Hall. On Monday evening the president's reception and dance for all members and guests will be held.

On Tuesday morning a drive around the Cornell campus with an inspection of the Home Economics College and Laboratories has been arranged, and on Tuesday afternoon there will be the outing and picnic at Taughannock State Park, with a picnic supper served along the lake front. Details of this excursion were given in the preceding issue. Return from the outing will be in time for the lecture to be given at Bailey Hall in the evening.

Wednesday morning and afternoon will be the trip to Corning, N. Y., home of the Corning Glass Works. Luncheon for the women only will be held at the Corning Country Club, and there will be a bridge party for those who do not desire to go through Watkins Glen in the afternoon. There will be a buffet supper at Corning in the evening. There will also be a musicale on Wednesday evening.

On Thursday morning there will be a putting contest followed by a luncheon in the Memorial Hall at Willard Straight Hall. The annual convention banquet, with dancing and other entertainment, will be held Thursday evening for all members and guests.

On Friday morning there will be an automobile trip to Enfield Glen and Falls at Enfield State Park; and the final get-together luncheon will be held Friday noon.

It was stated in the last issue that it will be necessary to charge moderate fees for certain entertainment events but the total amount of the fees for all of them will not exceed $6 per person. This will include the annual dinner, picnic at Taughannock State Park, luncheon, dance, and all other entertainment features regularly scheduled as part of the convention.

Housing

Facilities for living accommodations were outlined in the preceding issue, page 564, and rates for different arrangements were given there. As mentioned, living accommodations will be confined largely to the university dormitories located on the campus, although other facilities are available. An additional note regarding housing arrangements is that at the university dormitories, members who are attending with wives or families will be housed together, that is, they will be given double rooms or adjoining rooms. Balch Hall is arranged with 2 rooms forming a suite, with a connecting hall and lavoratory for the use of occupants. Risley Hall has a number of double rooms. It is the intention to house those guests with families in Balch Hall and Risley Hall.

Technical Sessions

The technical program is of broad scope and timely interest. Papers on some of the most recent developments in various fields of technical committee activities will be presented in 10 sessions: instruments and measurements, power generation, electrical machinery (2 sessions), protective devices, education, applications to iron and steel production, selected subjects, electrochemistry and electrometallurgy, and power transmission. The technical program and the papers for these sessions with reference to the issues in which they are published were given in Electrical Engineering for May 1935, page 561. In addition, Dr. D. B. Steinman, consulting engineer, has been invited to give a special address on "Engineers' Registration and Related Problems of the Profession" at the session on education, Wednesday morning, June 26. A paper entitled "Automatic Control for a Sheet Bar Roughing Mill" by L. A. Watson, Clark Controller Co., has been added to the session on applications to iron and steel production, Thursday morning, June 27. This paper is published in this issue. Other papers on the program appear in this and preceding issues. Excellent discussions by many well-known engineers are sure to result and when the meeting is opened for general discussion anyone in attendance should feel free to take part in the discussion.

Technical Conferences

Besides the formal technical program, 14 technical conferences on various subjects will be held during the afternoons for the benefit of specialists and the younger members. The schedule and the objectives of several of these conferences were announced in Electrical Engineering, May 1935 issue, pages 561–2. Additional information is given on the following conferences.

Problems of the Student and Cadet Engineer

The chairman of this conference, M. G. Malti, announces the following program subject to some modifications. After opening remarks by L. A. Doggett, Pennsylvania State College, and chairman of the committee on education, Bancroft Gherardi, vice president of the American Telephone and Telegraph Company, will outline "The Future of Engineering and the Young Engineer," and Dexter S. Kimball, Cornell University, will talk on "The Cadet Engineer in This Changing World."

After a period for discussion, another group of subjects will be lead off by Alan Howard of the General Electric Co., who will discuss "The Young Engineer in Industry" and W. H. Timbie, Massachusetts Institute of Technology, will bring out "The Value of an Engineering Education in a Nontechnical or Semi-Technical Career." Then R. E. Hellmund, Westinghouse Electric and Manufacturing Company, will discuss "Qualifications of a Successful Engineer."

Following another period of discussion, Chester L. Dawes, Harvard University, will tell about "The New Graduate School of Engineering" and a statement on the Engineers' Council for Professional Development, prepared by C. F. Hirshfeld, Detroit Edison Company, will be read by A. C. Stevens of the General Electric Company, after which will be another period for discussion.

Research on Insulating Oils

This conference will be under the chairmanship of Kenneth S. Wyatt, research department, The Detroit Edison Company, and its purpose is to provide an opportunity for informal discussion by those interested in the subject of insulating oils, with particular reference to the much needed research in that field, indicated by the following questions:

Is it not possible, by breaking away from lubricating oil ideas, to produce oils for electrical insulating purposes, of greatly improved stability? By using new methods recently available, such as solvent refining, is it not now possible to select those constituents of crude petroleum which have maximum stability for use in transformers, high voltage cables, circuit breakers, capacitors, and other electrical equipment? What special characteristics should an electrical insulating oil have, for transformers, for cables?

What are the chief causes of deterioration of electrical insulating oils in service? What are the factors influencing this deterioration? How can they be controlled? Before improved oils are produced, will it not be necessary, first, to discard old-time motor-oil routine tests, and to develop precision and micro-methods for detecting deterioration and for evaluating electrical stability?

What is the economic importance of the electrical insulating oil problem? How much could be saved annually in replacements both of oil and equipment, by reduction of hazard, and by increase of factor of safety, if improved oils could be made available to the industry?

Dielectric Theories

This conference with H. H. Race, chairman, will consider the theories of dielectric capacitance and dielectric loss in: (*a*) crystals; for example, ice; (*b*) the system, cellulose plus water; and (*c*) synthetic resins.

The present plan is to open the discussion by having the following speakers, Dr. E. J. Murphy, Bell Telephone Laboratories, Dr. J. B. Whitehead, The Johns Hopkins University, Dr. S. O. Morgan, Bell Telephone Laboratories, and Dr. J. D. Clark, General Electric Company, each present a 10 minute summary of important data and underlying theory. The major portion of the available time will be reserved for free informal discussion during which additional data, theories, and physical concepts may be presented in accordance with the interests and wishes of those attending the discussion.

Research in Engineering Schools

The purpose of this conference, under the chairmanship of Vladimir Karapetoff, school of electrical engineering, Cornell University, is to discuss the proper function of the teaching staffs of our technical schools in connection with research. It is expected that topics such as the following will be discussed: what have American schools of engineering contributed to the advancement of the art and science of electrical engineering through research and how does this record compare with European countries; research by faculty members, by graduate students and by undergraduate students; and what kinds of research problems can be undertaken by faculty members which would be most helpful to the industry and to the profession?

The last 3-mentioned technical conferences, which deal with research, have each been scheduled on different afternoons, in order not to conflict with one another.

The complete program and important information relative to very reasonable accommodations and reduced railroad rates was given in Electrical Engineering for May 1935, pages 561–4. Members in the nearby Districts who have received the registration and dormitory reservation cards should fill them in and post them promptly.

Avail yourself of the opportunity now to attend this interesting convention in a splendid scenic setting.

The Pacific Coast Convention

The 1935 Pacific Coast convention committee is actively engaged in formulating plans for the coming convention which will be held in Seattle, Washington, August 27–30. The Olympic Hotel, one of the finest and one of the most modernly equipped in the northwest, will be convention headquarters.

The tentative program provides for 5 technical sessions: power transmission and distribution, electrical machinery, communication, electrophysics and instruments and measurements, and selected subjects. A number of the papers will deal with the latest engineering developments in the Pacific Coast region and it is also being planned to hold an informal discussion of the Grand Coulee and Bonneville power projects on the Columbia River. In addition there will be 2 Student sessions.

The evenings will be devoted to social functions with a reception on Tuesday evening and a banquet and dinner-dance on Thursday evening. Facilities for sports and golf also will be available to members and guests. Arrange your vacation plans now and attend the Pacific Coast convention at Seattle the latter part of August.

Great Lakes District Meeting

The Great Lakes District of the A.I.E.E. will hold a meeting on the campus of Purdue University, West Lafayette, Ind., October 24–25, 1935. Headquarters will be in the electrical engineering building. A Student convention will be held in conjunction with the District meeting.

The technical program is being arranged under the direction of C. Francis Harding, chairman of the program committee. Several of the papers already have been prepared while others are well along in the course of preparation. Some of the subject matter will have to do with the production of standard impulse voltages, sphere gap breakdown as affected by ultra-violet light, the Purdue cathode ray oscilloscope, and the control of potential distribution over insulator surfaces. Other papers which deal with interesting and valuable researches in several different fields of activity will be scheduled on the program.

The personnel of the District meeting committee in charge of arrangements for this meeting was announced in Electrical Engineering, April 1935 issue, page 451.

1935 Lamme Medal Nominations Due Nov. 1

Special attention is directed to the fact that the names of Institute members who are considered eligible for the Lamme Medal, to be awarded in the fall of 1935 may be submitted by any member in accordance with Section 1 of Article VI of the by-laws of the Lamme Medal committee, as quoted in the following:

> The committee shall cause to be published in one or more issues of Electrical Engineering, or of its successors, each year, preferably including the June issue, a statement regarding the "Lamme Medal" and an invitation for any member to present to the national secretary of the Institute by November 1, the name of a member as a nominee for the medal, accompanied by a statement of his "meritorious achievement" and the names of at least 3 engineers of standing who are familiar with the achievement.

Each nomination should give concisely the specific grounds upon which the award is proposed, and also a complete detailed statement of the achievements of the nominee to enable the committee to determine

Aerial view of the north end of the campus of Cornell University, Ithaca, N. Y., showing the quadrangle, the engineering buildings, and to the right the Baker laboratory of chemistry. Many of the technical sessions during the Institute's forthcoming summer convention at Ithaca, June 24–28, will be held in the latter building. At the upper right-hand corner is Balch Hall, one of the dormitories which will be used for housing guests

its significance as compared with the achievements of other nominees. If the work of the nominee has been of a somewhat general character in co-operation with others, specified specific information should be given regarding his individual contributions. Names of endorsers should be given as specified above.

The Lamme Medal, founded as a result of a bequest of the late Benjamin Garver Lamme, chief engineer of the Westinghouse Electric and Manufacturing Company (deceased July 8, 1924), provides for the annual award by the Institute of a gold medal—together with bronze replica thereof—to a member of the A.I.E.E. "who has shown meritorious achievement in the development of electrical apparatus or machinery"; and for the award of 2 such medals in some years if the accumulation of funds warrants.

The seventh (1934) Lamme Medal has been awarded to Henry E. Warren (A'02) president of the Warren Telechron Company, Ashland, Mass., "for outstanding contributions to the development of electric clocks and means for controlling central station frequencies." Presentation will be made during the summer convention at Cornell University, Ithaca, N. Y., June 24–28, 1935. A brief biographical sketch of Mr. Warren appeared in ELECTRICAL ENGINEERING for March 1935, page 351.

Oklahoma City Section Is Host to Record Meeting of South West District

THE South West District's fifth District meeting, held in Oklahoma City, Okla., April 24–26, 1935, under the sponsorship of the Oklahoma City Section, established a new record for the District in total registration. The total registration of 571 not only topped the District's previous record of 541 set in 1929 at Dallas, Texas, but set a figure that in the history of the 30 Institute District meetings held since 1924 has been exceeded by only 3 other Districts, each of which has an Institute membership ranging from 230 to 490 per cent of the Institute membership in District 7. In point of average District meeting attendance as compared to District membership, District 7 now leads all Districts. Substantial delegations were present from each of the 6 Sections and 14 Student Branches in the District. Registration figures are given in an accompanying tabulation.

Technical Sessions

The popularity of the technical program was attested by the sustained heavy attendance at technical sessions and by the scope and character of the discussions. From the opening session Wednesday morning, with more than 250 present, to the closing session Friday afternoon, with more than 300 present, all sessions were punctual and heavily attended.

With but minor variations, the technical program presented was the same as that published in the March issue of ELECTRICAL ENGINEERING. Reflecting the useful flexibility of the Institute's present unified publication policy, 2 of the 7 formal technical papers were picked up for re-presentation from the 1935 winter convention papers previously published in ELECTRICAL ENGINEERING, 4 were published in the February, March, and April 1935 issues, and 1 will be published in a future issue. In addition to these 7 papers, 7 others of especial local interest were presented orally for discussion without publication or general circulation.

Presiding at the opening meeting Wednesday morning, F. J. Meyer, A.I.E.E. vice president from the South West District made some welcoming remarks, introduced the committee chairman in charge of key activities, and then called upon National Secretary H. H. Henline and Editor G. Ross Henninger, who respectively outlined briefly the history and trend of development of the Institute District meetings program and of its publication services. Presiding over the technical sessions were: R. F. Danner of Oklahoma City, Okla., and H. R. Fritz of St. Louis, Mo., for the opening general session; for the insulation and protection session Wednesday afternoon, O. S. Hockaday of Fort Worth, Texas, and L. C. Starbird of Dallas, Texas; for the second general session, Thursday morning, C. J. Hendricks of Fort Worth, Texas, and R. W. Linney of Oklahoma City; for the distribution and transmission session, Friday morning, D. D. Clarke of Kansas City, Mo.; and for the concluding general session, Friday afternoon, M. C. Hughes, College Station, Texas.

One of 2 special features was an informal "round-table" conference arranged informally for the evening of the first day in response to suggestions received by the program committee during the day. Embracing the general subject of rural electrification, and held on an entirely informal and spontaneous basis, this conference was expected to draw perhaps 25 interested persons. Instead it drew nearly 200 and lasted through the entire evening.

Symposium on Engineering Education

The second special feature, and the concluding item of the meeting program, was a "symposium on engineering education," a general discussion session led by discussions prepared in advance by J. B. Thomas, Texas Electric Service Co., Fort Worth, Tex.; T. F. McMains, Western Union Telegraph Co., Wichita Falls, Tex.; F. C. Bolton, Texas A. and M. College, College Station, Tex.; B. D. Hull, Southwestern Bell Telephone Co., Dallas, Tex., and I. H. Lovett, Missouri School of Mines and Metallurgy, Rolla, Mo.

Student Sessions

Student sessions were held Thursday and Friday mornings, in parallel with the general sessions. At these 2 sessions 14 excellent papers were presented:

WIDE RANGE REPRODUCTION IN SOUND ON FILM MOVING PICTURES, Ben H. Crowley, University of Oklahoma.

PROBLEMS IN TELEVISION, E. L. Kent, Kansas State College.

SEISMOLOGY IN PETROLEUM PROSPECTING, Philip W. Whitaker, Oklahoma A. & M. College.

THE CATHODE RAY OSCILLOGRAPH, James N. Walker, Southern Methodist University.

A PHOTOELECTRIC CELL SWEEP CIRCUIT FOR THE CATHODE RAY OSCILLOGRAPH, Erle Mayo and Marion Royalty, Texas Technological College.

Membership—

Mr. Institute Member:

The close of the fiscal year, April 30, 1935, showed the following number of applications received as compared with the year 1934:

	Year Ending April 30, 1934	Year Ending April 30, 1935
Number of applications received from enrolled Students	467	575
Number of applications received from all others	498	714
Total number of applications received	965	1289

Much of this increase came from your co-operation in sending in names.

Chairman National Membership Committee

ACOUSTICAL MEASUREMENTS WITH THE CATHODE RAY OSCILLOGRAPH, M. S. Burton, Texas A. & M. College.

GRID CONTROLLED, GASEOUS DISCHARGE TUBES, E. D. Hoffman, Missouri School of Mines and Metallurgy.

INVESTIGATION OF THE VARIATION IN THE VELOCITY OF LIGHT, Guy C. Omer, Jr., University of Kansas.

AN ALTERNATOR VOLTAGE REGULATOR UTILIZING A NON-LINEAR CIRCUIT, W. H. Mayne, University of Texas.

IMPULSE TESTING OF RUBBER, Hilton Remley, University of New Mexico.

ERRORS INHERENT IN AND CORRECTIONS TO BE APPLIED TO THE ELECTROMAGNETIC OSCILLOGRAPH, Walton J. Greer, Rice Institute.

SOME DEDUCTIONS FROM AND ILLUMINATION SURVEY, Glenn O. Ladd, University of Missouri.

ON MAGNETIC SIDE PULL, Jules R. Conrath, Washington University.

PRINCIPLES AND OPERATION OF SELSYN INSTRUMENTS, W. A. Fullwood, Jr., Southern Methodist University.

Although competing with the general sessions, the excellence of the student technical program kept the average attendance above 150 in addition to the 250 or more who attended the parallel general session.

In addition to the student technical sessions, the Enrolled Student delegation from each Branch in the District, together with their faculty counsellors, participated in the District's annual student conference which was held Friday morning. This session was presided over by Prof. J. A. Correll, counsellor of the Student Branch at the University of Texas, and chairman of the District committee on student activities. Each of the 14 Student Branches of the District was represented by its chairman, and 13 also by counsellors.

Branch counsellors present included: C. T. Almquist, University of Oklahoma, Norman; C. V. Bullen, Texas Technological College, Lubbock; J. A. Correll, University of Texas, Austin; E. H. Flath, Southern Methodist University, Dallas; R. G. Kloeffler, Kansas State College, Manhattan; A. C. Lanier, University of Missouri, Columbia; I. H. Lovett, Missouri School of Mines and Metallurgy, Rolla; E. W. Markle, Texas A. & M. College, College Station; Albrecht Naeter, Oklahoma A. & M. College, Stillwater; Chester Russell, Jr., University of New Mexico, Albuquerque; W. B. Stelzner, University of Arkansas, Fayetteville; R. W. Warner, University of Kansas, Lawrence; J. S. Waters, Rice Institute, Houston, Texas. Fifteen other faculty members from schools in the District were registered.

Student Branch chairmen present were: B. W. Crowley, University of Oklahoma; J. C. Evans, Washington University, St. Louis, Mo.; Glenn D. Farrar, Kansas State College; Walton Greer, Rice Institute; Frederic H. Holt, Missouri School of Mines and Metallurgy; T. B. Lewis, University of Arkansas; W. H. Mayne, University of Texas; Hiltom Remley, University of New Mexico; R. Roderick, Texas A. & M. College; Mark Townsend, Texas Technological College; Dan Weiser, University of Kansas; Philip R. Watson, University of Missouri; Philip W. Whitaker, Oklahoma A. & M. College; James N. Walker, Southern Methodist University.

The discussion covered many phases of Student Branch operating problems, an exchange of ideas concerning which within the District was deemed by all present to be of definitely practical value. One of the principal topics discussed was the question of what constitutes a desirable and effective program for Branch meetings. The discussion brought out that some meetings were conducted on the basis of a seminar in connection with the school program, some emphasized social features, and some depended largely upon "outside" features. It was considered worthy of particular note that there is an increasing tendency in the constructive direction of developing a greater interest and wider participation by the students themselves in presenting papers and discussions, either of an original nature or based upon papers for discussion published in ELECTRICAL ENGINEERING. There was unanimous agreement on the suggestion that some kind of refreshments served in connection with student branch meetings inevitably increased the attendance greatly.

At a group luncheon conference held by the counsellors Thursday noon, several routine matters of business of the District committee on student activities were brought up by District chairman J. A. Correll. Among the decisions arrived at were: an expression of satisfaction over the success of the student convention held jointly with the District meeting, and a recognition of the beneficial effect of having meeting room and facilities provided for the student sessions that were equally commodious and convenient to those provided for the general session; a 2-to-1 expression of opinion against the idea of offering local prizes for student papers. A discussion of the perennial question of traveling expenses brought from Secretary Henline an explanation that traveling expenses were authorized by the Institute for Branch chairmen and counsellors in a district to get together once a year for the purpose of discussing and perfecting branch activities from an operating viewpoint, and not for the purpose of promoting technical papers or a student technical program. It was suggested by one spokesman that it would be beneficial to all parties concerned for the counsellors' student activities committee to give branch officers more of a voice in determining District Student Branch policies.

Prof. R. G. Kloeffler, counsellor at Kansas State College, Manhattan, Kansas, was elected unanimously to serve as chairman of the South West District's student activities committee for the administrative year 1935–36.

Future AIEE Meetings

Summer Convention,
Ithaca, N. Y., June 24–28, 1935

Pacific Coast Convention,
Seattle, Wash., Aug. 27–30, 1935

Great Lakes District Meeting,
West Lafayette, Ind., Oct. 24–25, 1935

Winter Convention,
New York, N. Y., Jan. 28–31, 1936

North Eastern District Meeting,
New Haven, Conn., May 1936

Summer Convention,
Los Angeles, Calif., June 22–26, 1936

Middle Eastern District Meeting,
Akron, Ohio (date to be determined)

Analysis of Registration at Oklahoma City District Meeting

Classification	Location: Oklahoma City Section	District No. 7*	Other Districts	Totals
Members	80	75	21	176
Students	59	96	1	156
Men Guests (paying)	120	32	3	155
Women Guests	65	17	2	84
Totals	324	220	27	571

* Exclusive of Oklahoma City Section territory.

ENTERTAINMENT AND INSPECTION TRIPS

A well balanced program of inspection trips and entertainment activities provided excellently for the large number of men, women, and enrolled students present. Of the 5 inspection trips offered, 3 were to properties of the Oklahoma Gas and Electric Company, including a demonstration of insulation power factor testing equipment, and an inspection of downtown underground installations, the new Belle Isle gas burning power plant, and the load dispatcher's office. Other trips included a thorough inspection of the Oklahoma City oil fields, and a visit to the University of Oklahoma at Norman. In addition to those who made these trips in private groups, the official registration showed 211 participating in the various trips.

A golf tournament held Thursday afternoon drew 60 entries for the play which was held on the Oklahoma City Golf and Country Club's championship course.

In this competition, a registered guest, E. L. Blass, won the trophy cup put up by the golf committee, 79–9, 70. A. C. Bookout, of Oklahoma City, captured the runner-up trophy cup, 88–15, 73.

Entertainment features designed especially for women guests included, in addition to some of the inspection trips that appealed to the women, a tea held at the Y. W. C. A. Club House attended by 83, and a luncheon party at the Oklahoma City Golf and Country Club attended by 96. The principal general entertainment feature comprising a banquet followed by a parallel dance and bridge tournament was held Thursday evening with 390 in attendance.

DISTRICT EXECUTIVE COMMITTEE MEETING

For the purpose of completing items of business in connection with the District meeting, and to discuss other items of District business including tentative plans for a meeting suggested for San Antonio in 1937, the South West District executive committee convened for a luncheon meeting April 24. Vice President F. J. Meyer presided, and District Secretary C. W. Mier officiated in that capacity. Section officials present included: from Dallas, Past Vice President B. D. Hull, Section Chairman E. T. Gunther, and Secretary L. C. Starbird; from Houston, Section Secretary L. B. Bricker; from Kansas City, Section Chairman R. L. Frisby, and Secretary

H. V. Rathbun; from Oklahoma City, Section Chairman Albrecht Naeter, and Secretary C. E. Bathe; from San Antonio, Section Chairman J. W. Farrelly; from St. Louis, Section Secretary C. O. Campbell. Others present by request included A. C. Bookout, chairman-nominee for the Oklahoma City Section, National Secretary H. H. Henline and Editor G. Ross Henninger.

Report of Institute Committee on Sponsoring Discussions of Social and Economic Subjects

A SPECIAL committee on the question of sponsoring discussions on social and economic subjects was created by the Institute's board of directors in 1934. This committee, under the chairmanship of A. W. Berresford, past-president of the Institute, recently completed its report, and this report was approved by the board of directors at its meeting of May 21, 1935. The full text of the report, dated May 10, 1935, follows:

To the Board of Directors A.I.E.E.:

Gentlemen:

The action which created the committee was taken by the board at its meeting on June 27, 1934, and is as follows:

"Mr. Juhnke, as a result of attitudes he has encountered in his contacts with Enrolled Students and members of the Institute, suggested the desirability of the Institute's displaying an interest in the economic conditions of its membership by sponsoring social and economic discussions."

"Voted that the President be authorized to appoint a committee to consider the matter."

The committee has felt that the term "sponsoring" (the assumption of responsibility for) is probably broader in its implications than was the actual intent, and has therefore devoted its consideration to the desirability of such discussions and to recommendation of method by which, if initiated, they might accomplish their maximum value.

The committee recommends that discussions of the character contemplated in the motion be authorized in the national conventions and District meetings of the Institute, the meetings of its Sections, and of its Student Branches.

This recommendation is based on the following:

(*a*). There is growing realization that no single activity in our complicated social and economic structure is sufficient unto itself and in position to disregard the influence of its operations upon others or of the operations of others upon it.

(*b*). That this realization is important in the degree in which the activity itself is important.

(*c*). That in view of the importance of the engineering profession in the present stage of economic and social development, thought must be given to the conditions which it affects and which in turn affect it.

(*d*). That within the profession there is growing appreciation of the fact that, properly to fulfill his professional obligations, the engineer must possess qualification beyond the purely technical and extending into the cultural, social, and economic fields. This has been clearly enunciated in the progress reports of E.C.P.D. and is held to be warrant for considering these subjects as properly within the field of interest of an engineering body such as the Institute.

(*e*). That even under normal conditions these conclusions would have been reached, and that the effect of the existing confusion and uncertainty has been merely to accelerate realization.

(*f*). That in instinctive recognition of the need, and in increasing measure, such discussions have already become a factor in Institute procedure and the condition is less one of initiation than one of recognition and co-ordination.

In support of the above your committee cites that during the years 1933–34 there appeared in Electrical Engineering 23 articles dealing with social and economic subjects and aggregating 90 pages of material. Further, 37 items of similar character aggregating 83 fine print columns were printed; these consisting of "Letters to the Editor" and of news reports. While no actual comparison with earlier years has been attempted it is believed that review of the material indicated will demonstrate its value and pertinence.

Much of the matter contained in the papers is of exceptional character, and would form admirable text for discussions such as are proposed. The items and letters, save for material carried in A.E.C. and E.C.P.D. statements deal, as would be expected, with unit phases of the situation and would probably be of smaller value. There would seem to be a certain significance, however, in the fact that so many have yielded to a desire for expression and have expressed themselves sufficiently interestingly to attract editorial consideration. Undoubtedly, many were received which were not published.

Again, 274 papers presented before Section meetings during the period of September 11, 1933 to April 17, 1935 have been classified according to subject matter.

197 fell within the scope of the code of the meetings and papers (now technical program) committee of the A.I.E.E., edition of June 1929:

	No. Papers	
a to *m*. (Technical subjects) including 14 subjects on radio and television	194	
n. Co-operative activities of engineering professional organizations	0	
o. Ethical and social aspects of the profession and its members	3	
Total under code	197	72%

The remaining 77 papers were divided into the following 3 categories:

(*a*). History of A.I.E.E. and descriptions of meetings and conventions	10	
(*b*). Topics which depart from electrical engineering *per se* but which are of definite influence in the social and economic developments which directly affect electrical engineers or electrical engineering	39	
(*c*). Other branches of engineering, science, exploration, history, etc., not directly affecting electrical engineering or electrical engineers	28	
Total	77	28%

Note: This analysis does not include papers presented at 48 joint meetings of A.I.E.E. Sections with other professional societies such as A.S.M.E., I.R.E., I.E.S., etc.

Suggestions for Operation

It is evident that if such discussions are to become a recognized factor in Institute procedure, intelligent selection of subject matter is essential. This might be attempted by advance definition and limitation of the fields to be covered but your committee believes such procedure would prove not too satisfactory and perhaps not necessary. The desirable course would seem to be consideration specific to the individual instance rather than that of predetermination of general fields, and it would seem that existing Institute procedure would provide this.

Papers offered for presentation at general Institute meetings are subject to scrutiny and acceptance by committees organized to pass upon the value, desirability, and pertinence of the matter contained. Approval is essential to publication and presentation. When presented they become available for discussion by the Institute. Experience has proved the procedure to be necessary and adequate to technical presentation. It would seem equally applicable and adequate to subject matter of social and economic content.

To make the procedure effective it would be necessary only to broaden the definition of acceptable subject matter which is included in the code of the technical program committee. Your committee suggests that this might be done by adding a title as follows:

"Topics apart from electrical engineering *per se* but which are of definite influence in the social and economic developments which directly affect electrical engineering or electrical engineers."

If this were to be done your committee recommends that, to guard against misunderstanding, examples (*c*) and (*d*) of subjects *not suitable* for Institute presentation be retained in the code. These titles are as follows:

(*c*). Speculative and philosophical papers without electrical aspects.

(*d*). As abstract propositions not directly connected with electrical engineering—purely economic and allied studies such as rate making, project financing, obsolescence, depreciation, statistical methods, utility regulation, factory organization, etc.

Your committee further recommends that the Institute encourage discussion by Sections and Student Branches of subjects authorized by the above suggested procedure for publication or presentation. It feels that such encouragement might well include the direction of attention to the material available, co-operation by the staff in its preparation, in the securing of speakers, and the publication in Electrical Engineering of such transmitted reports of discussions as are deemed to be of general interest.

While making no recommendation for the inclusion of material other than that authorized for Institute presentation or publication, your committee notes that the publications of sister societies from time to time embody material of the nature contemplated. It would seem that, if authorized by the procedure above suggested, such material might be included in the lists of that available for discussion by Sections and Student Branches.

As instancing the character of material deemed suitable by your committee the

following titles appearing in ELECTRICAL ENGINEERING during 1933 and 1934 are cited:

April '33 —Private vs. Public Enterprise, Rautenstrauch
April '33 —Private Enterprise, Jordan
1933–34 —Reports and comments, E.C.P.D.
May '33 —Economic Forces (second report), A.E.C.
June '33 —Address to Student Branch Convention, E. E. Free
Aug. '33 —Communication (Engineer - Economists), Hirshfeld
Sept. '33 —Engineer and New Deal, Wickenden
March '34—Scientific Thought and Social Reconstruction, Mees
March '34—Social Aspects and Engineering Approach, H. A. Wallace
June, '34 —Engineering of Next Generation
June '34 —Making of a Profession, Wickenden
Nov. '34 —Engineering and the Economic Scene, Jordan and Chevalier

Respectfully submitted,
C. O. BICKELHAUPT
R. N. CONWELL
W. I. SLICHTER
A. W. BERRESFORD, *chairman*

A.I.E.E. Directors Meet at Institute Headquarters

The regular meeting of the board of directors of the American Institute of Electrical Engineers was held at Institute headquarters, New York, N. Y., on May 20, 1935.

There were present: *Past-Presidents*—H. P. Charlesworth, New York, N. Y.; and J. B. Whitehead, Baltimore, Md. *Vice Presidents*—F. O. McMillan, Corvallis, Ore.; and W. H. Timbie, Cambridge, Mass. *Directors*—L. W. Chubb, East Pittsburgh, Pa.; F. M. Farmer, New York, N. Y.; P. B. Juhnke, Chicago, Ill.; Everett S. Lee, Schenectady, N. Y.; A. H. Lovell, Ann Arbor, Mich.; and A. C. Stevens, Schenectady, N. Y. *National Treasurer*—W. I. Slichter, New York, N. Y. *National Secretary*—H. H. Henline, New York, N. Y.

In the absence of President J. Allen Johnson, on account of illness, Vice President Timbie presided.

Minutes were approved of meetings of the board of directors held January 21 and the executive committee on March 29, 1935.

Report of the executive committee of action, under date of April 12, 1935, admitting 361 applicants to the grade of Associate and enrolling 13 Students, was approved.

A report of a meeting of the board of examiners held April 24, 1935, was presented and approved. Upon recommendation of the board of examiners, the following actions were taken: 7 applicants were transferred to the grade of Fellow, 18 applicants were elected and 32 were transferred to the grade of Member, 236 applicants were elected to the grade of Associate, and 192 Students were enrolled.

The finance committee reported disbursements amounting to $17,345.86 in April and $18,427.78 in May. Report approved.

Section 14 of the by-laws was amended to read as follows:

"14. Any resignations received by the national secretary not later than June first of any year (September first in the case of members residing outside of the United States, Canada, and Mexico) may, at his discretion, be considered as having been received as of May first preceding. A resignation received after June first (or September first for nonresident members) shall involve payment of dues for that portion of the fiscal year ending with, and including, that quarter in which the resignation is received."

Upon request of the Indianapolis-Lafayette Section and recommendation of the Sections committee, an adjustment was made in the territory of that Section and its name was changed to Central Indiana Section.

The annual report of the board of directors to the membership, prepared by the national secretary, was approved for presentation at the annual meeting of the Institute in Ithaca, N. Y., on June 24, 1935. Contained therein were reports of general standing committees.

The annual report of the national treasurer was presented and accepted.

A report of the committee on award of Institute prizes covering the prizes awarded for papers presented in 1934 was received, and is published elsewhere in this issue.

In accordance with Section 37 of the constitution, the appointment of a national secretary for the administrative year beginning August 1, 1935, was made. National Secretary H. H. Henline was reappointed.

A report of the special committee appointed to consider the question of the Institute's sponsoring discussions on social and economic subjects was presented and adopted, and the committee was discharged, with an expression of the board's appreciation of its services. (The report is published elsewhere in this issue.)

The board approved A.I.E.E. representatives nominated by the committee on engineering schools of the Engineers' Council for Professional Development, for appointment as members of the delegatory committees in regions 1 and 2 (including the New England and Middle Atlantic States) in connection with the E.C.P.D. program for the accrediting of engineering schools.

An invitation was accepted to send delegates to the celebration, in Brussels, on June 13–15, 1935, of the fiftieth anniversary of the Societe Belge des Ingenieurs et des Industriels. A. S. Garfield, local honorary secretary of the Institute for France, and H. R. Summerhayes, of Schenectady, N. Y., were appointed as such representatives.

Other matters were discussed, reference to which may be found in this or future issues of ELECTRICAL ENGINEERING.

Guggenheim Aeronautic Medal Awarded. The 1935 Daniel Guggenheim medal for aeronautic achievement has been awarded to William Frederick Durand, professor emeritus of mechanical engineering at Stanford University, Calif. It was made "for notable achievement as pioneer in laboratory research and theory of aeronautics; distinguished contributions to the theory and development of aircraft propellers." The award was made by a board having 8 members in the United States, and 7 foreign members. Doctor Durand, a past president of the American Society of Mechanical Engineers, was a member of the Institute from 1912 to 1934. Previous recipients of the medal are Orville Wright (U.S.), Ludwig Prandtl (Germany), F. W. Lanchester (England), Juan de la Cierva (Spain), J. C. Hunsaker (U.S.), and W. E. Boeing (U.S.).

At Ithaca, 1935 Summer Convention Headquarters

A SCENE on the Ithaca (N. Y.) Golf Course, which, although obviously taken several years ago, will interest many of those attending the Institute's fifty-first annual summer convention on the campus of Cornell University at Ithaca, June 24–28, 1935. This golf course, just off the Cornell campus, overlooks Cayuga Lake, and is one of the best courses in the Finger Lakes region. In keeping with the policy of holding "a convention for the entire Institute," arrangements have been made so that the daily greens fee for this course for members and guests is $1. Other courses, too, are readily available in this region.

Section and Branch Activities Summarized in Annual Report for 1934–35

FOLLOWING the plan established in 1933, of publishing the annual report on Section and Branch activities in ELECTRICAL ENGINEERING instead of in pamphlet form, the report for the fiscal year which ended April 30, 1935, is presented here. Similar information for the fiscal year which ended April 30, 1933, was published in ELECTRICAL ENGINEERING for June 1933, pages 726–8, and for the fiscal year ending April 30, 1934, in ELECTRICAL ENGINEERING for June 1934, pages 1027–9.

The accompanying comprehensive summary constitutes a report upon the large and important division of Institute activities coming under the supervision of the Sections committee and the committee on Student Branches, the 2 committees being composed of the following personnel: Sections—I. M. Stein, *chairman*, L. A. Doggett, Mark Eldredge, F. A. Hamilton, Jr., A. P. Hill, W. H. Timbie, and, *ex-officio*, the chairmen of all Sections of the Institute. Student Branches—L. A. Doggett, *chairman*, R. B. Bonney, F. O. McMillan, Charles F. Scott, W. H. Timbie, and, *ex-officio*, all Student Branch counselors.

SECTION ACTIVITIES

During the fiscal year which ended April 30, 1935, there was no increase in the number of Sections (61), but the total number of meetings held was about 50 greater than that for the preceding fiscal year and the total attendance was virtually the same.

The New York and Chicago Sections continued their technical group activities substantially as they have been operated for several years. The Pittsfield and Schenectady Sections continued their annual competition among their younger members at 2 joint meetings, and the Boston and Lynn Sections inaugurated a plan for competition among their members in both the writing and presentation of papers, having 3 selected papers from each Section presented at a joint meeting, and awarding 3 prizes.

Other important developments in Section activities include: the formation by the Portland Section of technical committees on communication, industrial power applications, and transmission and distribution, which held 6, 9, and 6 meetings, respectively, for the presentation of technical material, with an average attendance of about 16; the holding of special technical meetings of the San Francisco Section between regular meetings (see page 454, April 1935 ELECTRICAL ENGINEERING); the holding of forum meetings between regular meetings of the Toledo Section, and also the plan of having a brief talk on fundamental electrical theory by a member of that Section during the first part of each regular meeting (see page 566, May 1935 ELECTRICAL ENGINEERING).

The Sections were urged by the committee on student selection and guidance of the Engineers' Council for Professional Development to co-operate with other engineering groups in supplying advice to boys thinking of entering engineering.

Detailed information on Section meetings during the past year is given in table I, and table II contains a brief summary of these meetings held during the last 3 fiscal years.

Table I—Section Meetings Held During Year Ending April 30, 1935

Section	A.I.E.E. Members: Aug. 1933	Aug. 1934	Meetings During Year: Number	Avg. Attendance	Avg. Attendance as Per Cent of Membership Aug. 1934
Akron	63	69	9	87	126
Alabama	19	39	4	21	54
Atlanta	65	76	4	—	—
Baltimore	157	157	9	204	130
Boston	377	370	6	238	64
Chicago	633	591	10	252	43
Power Group	.....	.....	3	101	.....
Cincinnati	146	140	11	92	66
Cleveland	193	200	8	147	74
Columbus	55	58	3	77	133
Connecticut	238	237	8	91	38
Dallas	78	78	9	67	86
Denver	130	130	9	96	74
Detroit-Ann Arbor	226	246	10	119	48
Erie	51	49	6	152	310
Florida	41	40	2	213	532
Fort Wayne	53	52	9	165	317
Houston	53	49	7	62	126
Indianapolis-Lafayette	73	85	5	138	162
Iowa	55	52	9	47	90
Ithaca	41	46	4	53	115
Kansas City	138	125	9	96	77
Lehigh Valley	176	176	9	166	94
Los Angeles	349	333	10	116	35
Louisville	48	46	7	77	167
Lynn	104	100	12	558	558
Madison	59	56	5	73	130
Memphis	30	29	12	58	200
Mexico	61	65	10	46	71
Milwaukee	161	153	18	138	90
Minnesota	79	76	6	60	79
Montana	31	29	6	19	66
Nebraska	45	46	1	49	107
New Orleans	32	42	5	66	157
New York	2,798	2,703	5	580	21
Communication Group	.....	.....	3	475	.....
Illumination Group	.....	.....	4	88	.....
Power Group	.....	.....	7	321	.....
Transportation Group	.....	.....	3	317	.....
Niagara Frontier	142	150	8	191	127
North Carolina	68	68	2	123	181
Oklahoma City	77	90	8	123	137
Philadelphia	529	512	7	170	33
Pittsburgh	409	383	8	242	63
Pittsfield	90	96	11	854	890
Portland	81	86	10	71	83
Communication	.....	.....	6	16	.....
Industrial Power Application	.....	.....	9	17	.....
Transmission & Distribution	.....	.....	6	15	.....
Providence	73	71	6	82	116
Rochester	64	59	10	119	202
St. Louis	195	173	7	124	72
San Antonio	40	30	9	43	143
San Francisco	379	359	8	119	33
Special technical meetings	.....	....	6	39	.....
Saskatchewan	31	23	7	30	130
Schenectady	335	350	15	167	48
Seattle	133	124	9	63	51
Sharon	50	50	8	153	306
Spokane	33	32	7	37	116
Springfield, Mass	72	69	9	72	104
Syracuse	62	62	4	234	377
Toledo	61	59	8	118	200
Toronto	302	287	14	116	40
Urbana	34	34	7	102	300
Utah	44	38	8	46	121
Vancouver	77	81	11	45	56
Virginia	72	81	4	113	139
Washington	155	173	8	140	81
Worcester	65	54	4	160	296
Total...61	10,531	10,337			

Total number of meetings............. 521
Total attendance..................... 73,381

Table II—Section Meetings Held During Last 3 Fiscal Years

	Fiscal Year Ending April 30: 1933	1934	1935
Number of Sections	60	61	61
Number of meetings held	498	472	521
Average number of meetings	8.3	7.7	8.5
Total attendance	73,806	73,271	73,381
Average attendance per meeting	148	156	141

BRANCH ACTIVITIES

During the past year, new Branches were organized at Brown University, Johns Hop-

Table III—Branch Meetings Held During Year Ending April 30, 1935

Branch	Meetings During Year: Number	Avg. Attendance	Approx. No. of Talks by Students
Akron, University of	1	9	
Alabama Polytechnic Institute	12	24	
Alabama, University of	11	39	14
Arizona, University of	23	7	20
Arkansas, University of	19	33	25
Armour Institute of Technology	9	52	
British Columbia, Univ. of	8	19	14
Brooklyn, Polytechnic Inst. of	7	57	7
Brown University[1]	4	32	
Bucknell University	4	15	1
California Institute of Tech	9	31	1
California, University of	11	45	3
Carnegie Institute of Tech	8	48	3
Case School of Applied Science	16	44	35
Catholic University of America	4	20	3
Cincinnati, University of	9	47	7
Clarkson College of Technology	3	28	
Clemson Agricultural College	7	37	15
Colorado State Agri. College	8	12	3
Colorado, University of	9	58	1
Cooper Union	—	—	
Cornell University	7	77	5
Denver, University of	15	22	
Detroit, University of	5	21	
Drexel Institute	19	25	12
Duke University	9	21	9
Florida, University of	12	59	2
George Washington University	7	43	1
Georgia School of Technology	5	22	
Harvard University	4	46	
Idaho, University of	10	54	2
Illinois, University of	4	97	3
Iowa State College	9	71	6
Iowa, University of	21	38	10
Johns Hopkins University[2]	1	30	
Kansas State College	10	68	4
Kansas, University of	11	46	6
Kentucky, University of	5	76	
Lafayette College	5	29	5
Lehigh University	6	66	3
Lewis Institute	5	73	
Louisiana State University	6	22	5
Louisville, University of	8	18	6
Maine, University of	5	26	
Marquette University	10	42	
Massachusetts Inst. of Tech	9	51	5
Michigan College of Min. & Tech	6	34	1
Michigan State College	1	18	
Michigan, University of	4	54	
Milwaukee School of Engineering	6	46	1
Minnesota, University of	8	33	4
Mississippi State College	7	15	11
Missouri School of Mines & Met	9	44	3
Missouri, University of	4	36	

Montana State College	18	31	48
Nebraska, University of	11	27	1
Nevada, University of	10	40	
Newark College of Engineering	7	27	12
New Hampshire, University of	20	26	33
New Mexico, University of	10	22	2
New York, Col. of the City of			
(Day division)	13	33	1
(Evening division)	5	47	
New York University			
(Day division)	12	16	40
(Evening division)	2	45	10
North Carolina State College	9	30	3
North Carolina, University of	8	36	4
North Dakota State College	8	16	10
North Dakota, University of	12	15	14
Northeastern University	3	21	
Notre Dame, University of	12	141	6
Ohio Northern University	—	—	
Ohio State University	9	43	1
Ohio University	3	16	1
Oklahoma A. & M. College	14	50	10
Oklahoma, University of	8	46	8
Oregon State College	8	70	3
Pennsylvania State College	8	107	5
Pennsylvania, University of	5	11	
Pittsburgh, University of	11	78	5
Porto Rico, University of	8	36	2
Pratt Institute	8	76	7
Princeton University	3	24	
Purdue University	5	60	1
Rensselaer Polytechnic Institute	6	119	4
Rhode Island State College	12	22	12
Rice Institute	8	17	4
Rose Polytechnic Institute	1	17	
Rutgers University	4	20	
Santa Clara, University of	5	28	3
South Carolina, University of	27	25	12
South Dakota State College	4	49	1
So. Dakota State School of Mines	6	18	
South Dakota, University of	7	6	
Southern California, Univ. of	15	31	11
Southern Methodist University	13	27	11
Stanford University	16	25	
Stevens Institute of Technology	6	24	
Swarthmore College			
Syracuse University	19	14	28
Tennessee, University of	8	26	1
Texas A. & M. College	3	47	1
Texas Technological College	7	27	4
Texas, University of	—	—	
Tufts College[3]	1	51	
Union College[4]	5	40	2
Utah, University of	4	18	1
Vermont, University of	7	18	
Villanova College	11	25	6
Virginia Military Institute	—	—	
Virginia Polytechnic Institute	29	48	30
Virginia, University of	6	19	6
Washington, State College of	10	40	
Washington, University of	11	39	6
Washington University	21	23	
West Virginia University	13	38	80
Wisconsin, University of	1	18	
Worcester Polytechnic Institute	4	44	
Wyoming, University of	9	11	2
Yale University	2	40	
Total	117		708

Total number of meetings 986
Total attendance 36,629

Authorized by board of directors:
1. August 7, 1934
2. January 21, 1935
3. January 21, 1935
4. December 7, 1934

Table IV—Branch Meetings Held During Last 3 Fiscal Years

	Fiscal Year Ending April 30		
	1933	1934	1935
Number of Branches	111	113	117
Number of meetings held	1,026	1,015	986
Average number of meetings	9.3	9.0	8.4
Total attendance	59,439	41,772	36,629
Average attendance per meeting	58	41	37
Number of student talks	982	1,004	708

kins University, Tufts College, and Union College, bringing the total number to 117.

Nearly all Branches carried on a normal amount of activity, but, the total numbers of meetings, student papers presented and attendance were smaller than for the preceding year.

Section and Branch co-operation was continued in many cases in which it had previously been established, and the students have shown an increasing interest in forming contacts with Institute members. Unusually successful student sessions were held at the District meetings in Worcester, Mass., and Oklahoma City, Okla., and at the Pacific Coast convention in Salt Lake City. The 5 such sessions held at these 3 meetings included a total of 19 papers; the attendance and interest were excellent.

1983 students were enrolled during the past year, and about 50 per cent of those whose terms expired April 30, 1935, applied for admission as Associates. Comprehensive information on Branch activities during the year is given in tables III to VII.

Table V—Comparison of Branch Activities by Districts

District	No. of Branches Jan. 1	Avg. No. Meetings per Branch	Avg. Attendance per Meeting	Approx. Avg. No. Student Talks per Branch	No. Branches Reporting 8 or More Student Talks
1	15	7.3	36	5.9	3
2	19	7.1	42	8.8	3
3	9	8.0	37	8.8	2
4	17	9.9	34	6.9	6
5	16	6.7	58	2.4	2
6	10	8.9	23	3.2	2
7	15	9.6	36	5.3	4
8	7	12.7	26	5.4	2
9	6	10.2	42	10.0	1
10	1	8.0	19	14.0	1

Table VI—Conferences on Student Activities

District	Location	Date
1	Worcester, Mass. (North Eastern District Meeting)	5/18/34
8 & 9	Salt Lake City, Utah (Pacific Coast Convention)	9/7/34
2	Carnegie Institute of Technology Pittsburgh, Pa	1/8/35
6	North Dakota State College Fargo, N. D	4/12, 13/35
4	Virginia Polytechnic Institute Blacksburg, Va	4/12/35
7	Oklahoma City, Okla. (South West District Meeting)	4/25/35

Section and Branch Joint Meetings

As stated above, co-operation between Sections and Branches continued to receive much emphasis. Table VIII contains brief information on some outstanding examples.

Table VII—Student Conventions

Sponsored by District	Location	Date	No. of Student Papers
1	Worcester, Mass. (No. Eastern District Mtg.)	5/18/34	7
8 & 9	Salt Lake City, Utah (Pacific Coast Convention)	9/4–5/34	12
1	Harvard University Cambridge, Mass	12/15/34	5
4	Virginia Polytechnic Institute Blacksburg, Va	4/12/35	6
6	North Dakota State College, Fargo, N. D	4/12, 13/35	
7	Oklahoma City, Okla. (South West District Mtg.)	4/25–26/35	12
New York Section	New York	4/26/35	5
2	Lafayette College Easton, Pa	4/29/35	5

Table VIII—Section or Joint Section and Branch Meetings With Active Student Participation

Sections	Schools	Date	Student Talks	Attendance
Oklahoma City	Oklahoma A. & M. College Univ. of Oklahoma	5/10/34	4	121
St. Louis	Missouri Sch. of Mines and Metallurgy Univ. of Missouri Washington Univ.	5/12/34	4	90
Cincinnati	Univ. of Cincinnati	5/14/34	5	130
Portland	Oregon State College	5/19/34	3	112
Iowa	Univ. of Iowa	11/14/34	1	54
Kansas City	Univ. of Kansas	11/15/34	2	95
Vancouver	Univ. of British Columbia	2/1/35	4	40
Dallas	Southern Methodist Univ	2/25/35	3	45
Spokane	Univ. of Idaho State College of Washington	3/22/35	2	74
Houston	Rice Institute A. & M. College of Texas	3/28/35	2	52
San Francisco	Univ. of California Univ. of Santa Clara Stanford Univ	4/11/35	3	69
Urbana	Univ. of Illinois Purdue Univ. Rose Polytechnic Inst. Washington Univ	4/13/35	3	200
Los Angeles	Calif. Inst. of Tech. Univ. of Southern Calif	4/16/35	5	145
Seattle	Univ. of Washington	4/16/35	2	120
Cleveland	Case Sch. of Ap. Science	4/18/35	3	93
North Carolina	Duke Univ. North Carolina State Col. Univ. of No. Carolina	4/26/35	3	114
Minnesota	Univ. of Minnesota	4/29/35	4	43

Student Conference Held by Southern District

A conference of the student Branches in the Institute's southern district, number 4, was held on the campus of Virginia Polytechnic Institute at Blacksburg, Va., April 11–13, 1935. The registration at this conference was 162, of which 87 were counselors and members of Branches and 75 were A.I.E.E. members from the Virginia Section, near-by West Virginia points, and a few interested nonmember visitors. In addition, the meetings were attended by a number of Virginia Polytechnic Institute faculty members and students. Delegates from 15 of the 17 student Branches in the southern district were in attendance. Prof. Claudius Lee, counselor of the local Branch, acted as chairman of the conference, and S. B. West, secretary of the local Branch and chairman-elect, acted as secretary.

Registration began the afternoon of April 11, and that evening about 250 persons were in attendance for a series of talking motion pictures presented by the American Telephone and Telegraph Company. Following this an informal smoker was held, presided over by Mr. West.

On April 12, the morning session was called to order by Prof. Claudius Lee, and R. L. Humbert formally welcomed the visitors on behalf of the V.P.I. The engineering department and the department of electrical engineering were then represented by E. B. Norris and Dr. S. R. Pritchard, respectively. The technical session and presentation of student papers followed. The papers were:

Some Additional Litchenberg Figures, by R. B. Hutchins, University of Alabama.

The Photo-Voltaic Cell in Photometry, by O. D. Lyon, Georgia School of Technology.

The Tennessee Valley Authority—An Experiment, by H. P. Cotton, North Carolina State College.

A Vacuum Tube Voltage Regulator, by R. F. Hays, Jr., Mississippi State College.

An Experimental Vacuum Tube Voltmeter, by S. A. Black and C. C. Jones, University of South Carolina.

An Application of Operational Calculus to an A-C Circuit, by I. G. Foster, Virginia Military Institute.

A very encouraging sign was the high quality of the papers presented, and the fact that every one of them provoked some discussion. Prizes for these papers were awarded, the judges of the contest being: F. M. Craft, vice president A.I.E.E. Southern District; Dean S. B. Earle, Clemson College, South Carolina; and Dean W. S. Rodman, University of Virginia. The paper by Mr. Hutchins was awarded first prize of \$15; that by Mr. Cotton, second prize of \$10; and that of Mr. Foster, third prize of \$5.

Following the technical session the conference went into a business session. It was voted that the next student Branch conference of the Southern District be held at Clemson College, South Carolina, and Prof. S. R. Rhodes was unanimously elected chairman of the student Branch conference for the ensuing year. Professor Rhodes also was unanimously elected to represent the conference at the A.I.E.E. summer convention at Ithaca, N. Y., June 24–28, 1935. A questionnaire is to be sent out to determine the most desirable date for holding the District's next conference.

Professor Lee delivered a report on the Institute's annual convention at Hot Springs, Va., June 1934, and on the plans discussed for betterment of student activities. Among other subjects considered, Vice President Craft suggested that the present method of Electrical Engineering in handling student activities appeared to be very good, and advised all students to read this publication religiously. The chairman then expressed his thanks to all committees, counselors, Students, and volunteers who had helped to make the conference so successful.

Following this afternoon business meeting, visitors inspected the various departments and near-by points of interest. At the dinner meeting that evening, A. J. Francis, vice chairman of the V.P.I. Branch, presided. Vice President Craft awarded the prizes for the Student papers, after which an informal social session was held.

The concluding day, April 13, was reserved for inspection trips to several nearby points of interest.

Engineering Boards Hold Joint Conclave

WHAT are the professional engineering societies doing to advance the profession and practice of engineering in the interest of professional advancement and of effective service to American business and industry?

For the purpose of answering this and related questions through the medium of "verbal diorama," a large proportion of the officers and directors of the national societies of civil, mining and metallurgical, mechanical, and electrical engineers, together with members of the governing bodies of their several jointly sponsored functional organizations, met for dinner and a general conclave Monday evening, May 20, 1935, at the Engineers' Club in New York. Including a few special guests, a total of 89 persons were present. This was the first time in the history of the societies that a meeting of such ambitious scope had been undertaken, although in 1933 at Chicago, and perhaps once or twice in earlier years, joint meetings had been undertaken. The one claimed by A.I.E.E. Past-President Charles F. Scott as being the very first, was the "First Founders Feast" reported to have been held one evening in the spring of 1907 in the then new Engineering Societies' Building "shortly before its formal dedication and when there was some scaffolding in the large room on the fifth floor in which the table was set."

The prime purpose of the meeting of May 20, 1935, was to provide an effective opportunity for an increase in knowledge, understanding, and general interest in the various phases of the work of the several joint organizations created by the national societies to serve the engineering profession. Toward this end, carefully prepared concise statements covering the scope and significance of the work of each of the 8 jointly sponsored organizations were delivered at the meeting. The subjects of these statements, and the men who presented them, are as follows:

1. United Engineering Trustees, Inc., by Harold V. Coes, president of U. E. T.; past vice president of the American Society of Mechanical Engineers; manager, industrial department, Ford, Bacon and Davis, Inc., New York, N. Y.

2. Engineering Societies Library, by Walter I. Slichter, treasurer American Institute of Electrical Engineers; professor of electrical engineering, Columbia University, New York, N. Y.

3. Engineering Foundation, by H. P. Charlesworth, chairman Engineering Foundation Board, junior past-president American Institute of Electrical Engineers; assistant chief engineer, American Telephone and Telegraph Company, New York, N. Y.

4. American Standards Association, by Howard E. Coonley, president A. S. A.; president Walworth Company, New York. In Mr. Coonley's enforced absence, the statement was read by F. E. Moskovics, vice president A. S. A.; chairman of the board of the Marmom Harrington Company, Indianapolis, Ind.; vice president, Frederick H. Levey, Inc., 59 Beekman Street, New York, N. Y.

5. Division of engineering of the National Research Council, by Dr. D. S. Jacobus, vice chairman of the division; past-president American Society of Mechanical Engineers; advisory engineer, Babcock and Wilcox Company, New York, N. Y.

6. Engineering Societies Employment Service, by George T. Seabury, chairman of the National Advisory Board; secretary American Society of Civil Engineers, New York, N. Y.

7. American Engineering Council, by J. F. Coleman, president A. E. C.; past-president American Society of Civil Engineers; consulting engineer, New Orleans, La.

8. Engineers Council for Professional Development, by Dr. C. F. Hirshfeld, chairman E.C.P.D.; chief of research department, Detroit Edison Company, Detroit, Mich.

9. "Industrial Prospecting," a special address prepared by Dr. Charles F. Kettering, chairman of the division of engineering of the National Research Council; vice president General Motors Corporation; president General Motors Research Corporation; read in Doctor Kettering's absence by Maurice Holland, director of division of engineering and industrial research, National Research Council, New York, N. Y.

Presiding officer for the gathering was Arthur F. Tuttle, president American Society of Civil Engineers; New York state engineer, Federal Emergency Administration of Public Works. Toastmaster for the evening was Dr. Harvey N. Davis, president Stevens Institute of Technology, Hoboken, N. J.; past-president American Society of Mechanical Engineers. Honored guests were: Dr. Charles F. Scott of New Haven, Conn.; past-president A.I.E.E.; professor emeritus of electrical engineering Yale University; prime mover and cofounder of the project that nearly 30 years ago led to the realization of the dream of an Engineering Societies Building as the national home of the national professional societies; and Dr. Isaiah Bowman, president-designate of The Johns Hopkins University, Baltimore, Md., and chairman of the National Research Council.

Following the presentation of the several highly informative short addresses (the substance of which is scheduled to be reflected generously in a subsequent issue of Electrical Engineering) there was a discussion participated in by many who were interested in different phases of the varied

work described. At the close of this session, Toastmaster Davis capped a fitting climax upon a successful evening by calling, without warning, upon Dr. Alfred D. Flinn, for more than 17 years director of Engineering Foundation, and its devoted, inspiring leader. Doctor Davis aptly characterized Doctor Flinn of being responsible more than any other individual for the evolution of effective co-operation of the founder societies and their functional organizations. In his brief response Doctor Flinn paid tribute to Dr. Ambrose Swasey, founder of the Engineering Foundation "as an institution for the furtherance of research in science and engineering, or for the advancement in any other manner of the profession of engineering and the good of mankind." As tangible evidence of the work being done, Doctor Flinn urged critical consideration of the several reviews and reports presented.

Among the large delegation of Institute members present were many who, in addition to their Institute affiliation, were present as representative officers or board members of other societies or of one or more of the 8 joint functional organizations. Those present included the following (initials in parenthesis indicate representation of organization other than A.I.E.E.):

P. G. Agnew, New York, N. Y.; (ASA).
A. W. Berresford, past-president, New York, N. Y.; (AEC).
C. O. Bickelhaupt, past vice president, chairman publication committee, New York, N. Y.; (AEC, ECPD).
H. P. Charlesworth, junior past-president, New York, N. Y.; (EF; UET).
F. J. Chesterman, past director, Pittsburgh, Pa.; (AEC).
L. W. Chubb, director, East Pittsburgh, Pa.
P. H. Daggett, New Brunswick, N. J.; (ECPD).
F. M. Farmer, director, chairman research committee, New York, N. Y.
H. H. Henline, national secretary, New York, N. Y.; (ECPD, Library).
G. Ross Henninger, editor, New York, N. Y.
C. F. Hirshfeld, Detroit, Mich.; (ECPD).
Maurice Holland, New York, N. Y.; (NRC).
D. S. Jacobus, New York, N. Y.; (NRC).
F. B. Jewett, past-president, New York, N. Y.; (NRC).
P. B. Juhnke, director, Chicago, Ill.
G. L. Knight, past vice president, Brooklyn, N. Y.; (UET).
E. S. Lee, director, chairman membership committee, Schenectady, N. Y.
A. H. Lovell, director, Ann Arbor, Mich.
J. H. McGraw, Sr., New York, N. Y.
F. O. McMillan, vice president, Corvallis, Ore.
C. F. Scott, past-president, New Haven, Conn.; (ECPD).
W. I. Slichter, treasurer, New York, N. Y.; (EF, Library).
C. E. Stephens, past director, chairman committee on code of principles of professional conduct, New York, N. Y., (AEC).
A. C. Stevens, director, Schenectady, N. Y.
R. H. Tapscott, director, chairman finance committee, New York, N. Y.
W. E. Wickenden, Cleveland, Ohio; (ASME, ECPD).
H. R. Woodrow, director, Brooklyn, N. Y.; (UET).

Institute Prize Awards Announced for 1934 Papers

FOUR national prizes for papers presented during the calendar year 1934 have been announced by the committee on award of Institute prizes, which consists of R. N. Conwell (A'15, F'31) chairman, C. O. Bickelhaupt (M'22, F'28), and F. M. Farmer (A'02, F'13). These prizes in each case consist of a suitable certificate. Personal presentation of the prizes will take place at the opening session of the Institute's summer convention to be held on the campus of Cornell University, Ithaca, N. Y., June 24–29, 1935.

Authors presenting papers which are eligible for future prizes should bear in mind that to be considered for prizes, papers must be submitted specifically for this purpose to the proper committee. Prize consideration is not given automatically to all papers published or presented at conventions or meetings.

National Prizes

After due consideration of all highly recommended papers, the committee on award of Institute prizes made the following awards of national prizes for papers presented in 1934:

Best Papers

Prize for best paper in engineering practice was awarded to J. Allen Johnson (A'07, F'27 and president) and R. T. Henry (A'24, F'33) for their paper "Fundamentals of Design of Electrical Energy Delivery Systems," published in ELECTRICAL ENGINEERING for December 1933, pages 831–8, and discussed at the winter convention, New York, N. Y., January 23–26, 1934.

Honorable mention was made of "Auditory Perspective—Transmission Lines," by H. A. Affel (A'18, M'23), R. W. Chestnut (A'19) and R. H. Mills (A'33) published in ELECTRICAL ENGINEERING for January 1934, pages 28–32, and discussed at the winter convention, New York, N. Y., January 23–26, 1934.

Prize for best paper in theory and research awarded to H. S. Black (A'23, M'33), for his paper "Stabilized Feedback Amplifiers," published in ELECTRICAL ENGINEERING for January 1934, pages 114–20, and discussed at the winter convention, New York, N. Y., January 23–26, 1934.

Honorable mention was made of "High Frequency Induction Furnaces" by C. A. Adams (A'94, F'13, member for life and past-president), J. C. Hodge, and M. H. MacKusick, published in ELECTRICAL ENGINEERING for January 1934, pages 194–205, and discussed at the winter convention, New York, N. Y., January 23–26, 1934.

Prize for best paper in public relations and education was awarded to C. F. Hirshfeld (A'05) for his paper "Engineers of the Next Generation" published in ELECTRICAL ENGINEERING for June 1934, pages 857–9, and discussed at the summer convention, Hot Springs, Va., June 25–29, 1934.

Honorable mention was made of "Encouraging Initiative in the Engineering Student" by C. L. Dawes (A'12, M'15), published in ELECTRICAL ENGINEERING for June 1934, pages 910–14, and discussed at the summer convention, Hot Springs, Va., June 25–29, 1934.

Initial Paper

Prize for initial paper was awarded to J. R. Meador (A'34), for his paper "Calibration of the Sphere Gap," published in ELECTRICAL ENGINEERING for June 1934, pages 942–8, and discussed at the summer convention, Hot Springs, Va., June 25–29, 1934.

Honorable mention was made of the following papers: "Wide-Band Open-Wire Program System" by H. S. Hamilton (M'24), published in ELECTRICAL ENGINEERING for April 1934, pages 550–62, and discussed at the Pacific Coast convention, Salt Lake City, Utah, Sept. 3–7, 1934; and "Trolley Wire Lubrication Improved" by J. V Lamson (A'29) published in ELECTRICAL ENGINEERING for November 1933, pages 771–6, and discussed at the winter convention, New York, N. Y., January 23–26, 1934.

In the class of the national prize for Branch papers only 2 papers were submitted. These papers received low gradings and were not recommended to be of sufficient value to warrant publication unless extensively revised. The committee recognizes the need to encourage the preparation and presentation of Branch papers, but, as only 2 papers were submitted and as neither of these was considered to be up to the standard of Branch papers, the committee did not award a national prize for Branch papers this year.

In each of the other classes of prizes the committee considered a number of papers which were of universally high caliber so that the task of choice between them was a difficult one. Commendation was extended to all authors for the high standard of papers and to the technical committee for their work in sponsoring a number of the papers and grading them at the same time they were initially reviewed, which has been of valuable assistance to the committee on award of Institute prizes in determining the most worthy papers for the awards.

District Prizes

District prizes as announced by 3 Districts to date include 2 awards of $25 each, together with appropriate certificates. Other District awards will be announced in subsequent issues, as the information becomes available.

District No. 1

Prize for Branch paper awarded to Albert E. French for his paper "The Place of Operational Calculus in Undergraduate Study of Electrical Engineering," presented at the North Eastern District Meeting, Worcester, Mass., May 16–18, 1934.

District No. 7

Prize for Branch paper awarded to Ralph A. Galbraith for his paper "Torque-Angle Characteristics of Synchronous Motors," presented at a joint meeting of the St. Louis Section, University of Missouri Branch, Missouri School of Mines and Metallurgy Branch, and Washington University Branch, May 12, 1934.

District No. 10

Prize for best paper awarded to H. Forbes-Roberts (A'25) for his paper "The British National Grid System," presented at meeting of the Saskatchewan Section, April 25, 1934.

Smoke Abatement Rules Published. "To insure construction of new plants and buildings and changes in existing plants being done in such a manner that smoke will not be made," the department of smoke regulation of the board of health and vital statistics of Hudson County, N. J., has issued a comprehensive pamphlet of rules and regulations governing details of fuel burning equipment required for the issuance of permits and certificates. This edition is revised as of March 1935. Copies of the pamphlet are reported as available to members of the Institute who will forward 3 cents postage to the department at the Court House, Jersey City, N. J.

E.C.P.D. Offers a Method of Self-Appraisal as a Basis for Post-College Training

WHEN does an engineer's education end? With his graduation from college? Or is further self-development necessary to enable the junior engineer to take responsible charge of engineering work, become a valuable member of society, and gain professional recognition?

In the opinion of the Engineers' Council for Professional Development, the years immediately after graduation from an engineering school are not only fruitful years for growth and development, but critical years in the young graduate's progress toward the goal of public recognition as a full-fledged engineer. It is the function of the E.C.P.D. committee on professional training to offer a program for further intellectual development that will bridge this gap between graduation, or its equivalent, and professional recognition.

The Engineers' Council for Professional Development is a conference of engineering bodies organized to enhance the professional status of the engineer by promoting higher standards of education and practice, and greater effectiveness in dealing with technical, social, and economic problems. It derives its existence and authority from 7 constituent bodies representing the technical, educational, legislative, and professional phases of an engineer's life—the American Society of Civil Engineers, American Institute of Mining and Metallurgical Engineers, The American Society of Mechanical Engineers, American Institute of Electrical Engineers, American Institute of Chemical Engineers, Society for the Promotion of Engineering Education, and National Council of State Boards of Engineering Examiners.

The program of E.C.P.D. is embodied in the work of 4 major committees dealing with: (1) the selection and guidance of prospective engineering students; (2) the accrediting of engineering schools worthy of recognition; (3) the further professional and personal development of junior engineers; and (4) the formulation of minimum standards for professional recognition. Information regarding the E.C.P.D. and the activities of its committees can be obtained from the secretary of the E.C.P.D., 29 West 39th St., New York, N. Y.

Professional Training

Genl. Robert I. Rees, assistant vice president of the American Telephone and Telegraph Company, and chairman of the E.C.P.D. committee on professional training, recently outlined the program for junior engineers. "It is incumbent upon us," he said, "to prepare sound programs for the guidance of the intellectual development of the young engineer after he gets into practice. It is particularly important to stimulate his growth in cultural, social, and economic subjects, for the study of which his college course necessarily left little time."

For juniors and those who are about to enter the engineering profession, General Rees's committee has prepared a personal appraisal questionnaire that offers opportunity for a searching self-analysis of the individual's status. This questionnaire has been published to assist those who are looking forward to an engineering career, or in obtaining a broader appreciation of their own interests and ability and in planning a definite program of self-development. In this way, the committee hopes ultimately to bring about a higher level of professional attainment and consciousness. If the young graduate will thoughtfully and honestly answer the 65 questions in the appraisal regarding his present occupation, his professional status, his personal relations, and his general program of development, he should be able to outline an immediate plan of study based upon his individual strength and weakness, his background, and ambition. The committee has suggested that in using the list it be read over carefully first, and the questions raised and pondered upon for a few days, and perhaps discussed with intimate friends or an older man with sympathetic understanding whose judgment is trusted.

The questions contained in the list are as follows:

Occupation

1. What are the duties and responsibilities of my present job?

2. Have I the general education needed to do this job well? If not, what additional courses should I take, or what reading should I do?

3. Have I the knowledge of my duties, department, and company needed to enable me to do my job well? Can I gain additional knowledge through training courses, reading, or by better use of my experience, and by a broader range of contacts? If so, how?

4. Do I carry out assignments on time and in such a way that my work meets professional engineering standards and requires little, if any, revision? Is there additional work, beyond the routine assignments, which I might properly do? How can I improve my performance in these respects?

5(*a*). Does a condition of mutual respect and cordiality exist in the relations between my superiors and me? If not, is it because my work is not of the right quality; am I either too timid, or over aggressive; or do I lack understanding of my responsibilities? What steps should I take to strengthen the relations between my superiors and me?

5(*b*). Are my relations with my associates cordial and friendly? Am I doing my full share to promote such desirable friendly relations? Do I try to appropriate all the credit or shift the blame?

5(*c*). Is there friendliness and mutual respect between my subordinates and myself? Are my instructions to them always clear and complete? Do I supervise properly to make sure that those instructions are understood and at the same time do I avoid unnecessary interference in the execution of my orders? Do I insist upon good work from my subordinates, and do I give proper credit for work well done? Am I genuinely interested in the ambitions, problems, and well-being of my associates and subordinates?

5(*d*). Are my contacts with the customers or clients of my company and other members of the public friendly and effective?

6. Have I seen ways by which the accomplishment of my work and that of the group of which I am a member can be improved? Have I formulated any such ideas and examined them carefully? Have I taken the initiative in presenting for consideration

Grand Coulee Dam in the Columbia River Basin

LOOKING upstream at the site where Grand Coulee Dam is being constructed on the Columbia River in the eastern part of north central Washington, 80 miles west of Spokane. At the right, beyond the second bridge, may be seen one section of the cofferdam which is now under construction. The second coffer will be built on the opposite bank, and the third, to be completed in 1937, will consist of 2 rows of cellular sheet steel piling driven across the channel, 1 upstream and 1 downstream from the dam. At the right also may be seen the huge conveyer which carries excavated material from the dam site into a near-by canyon. The Government camp site may be seen at the right, and across the river, at the left, is Mason City, the contractor's town site. Inasmuch as the Grand Coulee project is (in a direct line) some 150 miles east of Seattle, it may be inspected by those attending the Institute's Pacific Coast convention in Seattle, August 27–30, 1935.

such ideas as, after serious consideration, still seemed sound? Has my presentation to my superiors and associates been clear, concise, and convincing?

7. Does my work suffer from the lack of physical vigor or from the wrong emotional attitude? How can I overcome any such handicaps?

8. For what general fields of activity am I best fitted by education, aptitude, and interest? Does my present work lead to development in such a field?

9(*a*). Does the company with which I am now connected have the right fields of activity to offer me and does it also offer the ideals, associations, and opportunities for advancement which I may reasonably expect?

9(*b*). If not, when and where should I seek a connection with genuinely greater promise in these respects?

10. What advanced positions, therefore, in my own company or elsewhere should I now prepare for? What are their duties and responsibilities? What further training, both along technical and economic or social lines, should I now begin; what added experience should I seek; and what personal qualities should I try to develop in preparation for such advancement?

PROFESSIONAL STATUS

1. What requirements for full membership in my professional society do I now fail to satisfy? What steps, beyond those already planned, should I take to correct my present deficiencies? When should I plan to attain full society membership?

2. Do I possess the qualifications which give eligibility for a professional degree in engineering? If not, what additional requirements must I satisfy to become eligible? Should I plan to secure such a degree? If so, how should I proceed?

3. Does my position and do my ambitions make it desirable for me to become a registered professional engineer? If I wish to do this, what steps should I take to meet the requirements? How soon should I plan to apply for registration?

PERSONAL STATUS

1. In terms of family relationships, what are my ambitions and what goals shall I set now? Are my education and cultural background adequate for the realization of my ambitions? If not, can I improve myself by taking courses or by reading beyond that already suggested?

2. What physical, personal, or emotional shortcomings may tend to prevent full realization of my ambitions? What steps should I take to overcome these handicaps?

3. Is my financial status adequate to enable me to reach my goal? If not, what program should I develop and put into practice?

4. As a neighbor and citizen, what place in my community and in government should I take? How can I prepare myself to carry out my community and political responsibilities more fully?

5. Am I developing my capacity for friendship and utilizing opportunities for broadening the circle of which I am a part? Do I contribute my share in the give and take of these relationships? Do I enjoy the social contacts which I have? How should I change my attitude or develop my personal qualities to deepen and extend my friendships?

6. What avocation, recreations, sports, or hobbies would be best suited to round out my life?

GENERAL PROGRAM OF DEVELOPMENT

1. On the basis of this appraisal, what educational courses and reading should I undertake during the next few years?

2. What experience should I seek, and how can I best utilize it?

3. What personal attitudes and qualities should I cultivate?

4. What health program should I follow?

5. What financial program should I lay out and try to carry through?

6. In what professional, civic, and social activities should I participate, and to what extent?

7. What program of sport, recreation, or avocation should I plan?

IMMEDIATE PROGRAM

What definite steps in each classification should I take *now* to reach, within a reasonable time, the various goals set for myself?

The questionnaire has been published in a 12-page $8^1/_2$ x $11^1/_4$-inchp amphlet which contains, following an introductory explanatory note, the 65 questions above, specially arranged with blank spaces for the answers to be written in. In addition, the pamphlet contains "Reading Lists for Junior Engineers" comprising over 100 titles of suggested books. This list has been published month by month in ELECTRICAL ENGINEERING as follows: December 1934, page 1667; January 1935, page 133; March 1935, page 345; April 1935, page 456; May 1935, page 569; and June 1935, page 681.

The pamphlet, containing both lists, and entitled "Suggestions for Junior Engineers," may be obtained from the secretary of the E.C.P.D., 29 West 39th Street, New York, N. Y. It is priced at 10 cents per copy, and 5 cents per copy in quantities of 50 or more.

S.P.E.E. Investigation of Engineering Education Reported Upon

SUFFICIENT interest has been exhibited in the investigation of engineering education that was carried on for several years by the Society for the Promotion of Engineering Education, to warrant calling attention of members of the Institute to the availability of the published report on this investigation. The investigation was "directed to a study of the objects of engineering education and of the fitness of the present day curriculum for preparing the student for his profession." The main investigation was carried on during the period from 1923 to 1929, with further investigation of particular phases extending to 1934.

Since its inception the investigation has been supervised by the board of investigation and co-ordination of the S.P.E.E., with Dr. Charles F. Scott (A'92, M'93, F'25, HM'29, past-president, and member for life) as its chairman. The work of the investigation was carried on by Dr. W. E. Wickenden (A'09, M'13) director of investigation, 1923–29, and H. P. Hammond, associate director, 1924–29, and director of summer schools, 1927–33. Doctor Scott is professor of electrical engineering, emeritus, Yale University, New Haven, Conn.; Doctor Wickenden is president of Case School of Applied Science, Cleveland, Ohio; and Professor Hammond is professor of civil engineering, Polytechnic Institute of Brooklyn, Brooklyn, N. Y.

COMPLETE REPORT AND SUMMARY OF RESULTS ARE AVAILABLE

Various bulletins and reports on the investigation were presented from time to time in the S.P.E.E. monthly publication and in pamphlet reprints. These and other reports then were brought together in revised form in a complete report of 2 volumes. These volumes, entitled "Reports of the Investigation of Engineering Education 1923–1929" including the report on summer schools for engineering teachers (1927–1933), accompanied by a supplemental report on technical institutes (1928–1929), and with bibliographies and indexes, may be obtained from F. L. Bishop, secretary of the Society for the Promotion of Engineering Education, University of Pittsburgh, Pittsburgh, Pa., at \$3 each, or \$5 per set of the 2 volumes which total some 1,670 6 x 9-inch pages. Volume 1 is dated 1930, and volume 2, 1934.

The final report of Doctor Scott as chairman of the board of investigation and co-ordination is a summary of the results of the investigation, and appears as pages 1237–73 of volume 2 of the complete report. This "Summary of Results" also has been published as a pamphlet reprint $5^3/_4$ x $8^1/_2$ inches in size, copies of which may be obtained from F. L. Bishop, secretary of the S.P.E.E., University of Pittsburgh, Pa., at a cost of 10 cents each, or \$7.50 per hundred. This summary is stated to be "frankly somewhat personal in that emphasis is laid on features appealing to the writer as most significant."

CONTENTS OF THE COMPLETE REPORT

Some conception of the scope of the investigation and the tremendous amount of data on many phases of engineering education contained in the complete report may be gained from the following foreword printed in volume 1:

"The ..... report marks the culmination of a comprehensive study directed to the improvement of engineering education proposed in 1922 and undertaken in 1923 by the Society for the Promotion of Engineering Education.

"The enterprise was inaugurated as a co-operative undertaking in which the schools should actively participate. The work was planned and conducted by a staff under the direction of a board of investigation and co-ordination. The schools supplied data in connection with the extended fact-finding features of the investigation and contributed through special and local committees in the study of particular problems and in other ways. Engineering societies, industry, governmental agencies and individuals co-operated.

"The assemblage of facts and data pertaining to the field of engineering education affords a definite idea of what is now being done. It presents to those who are familiar only with the particular institutions or fields of work in which they are engaged a general view; the present study integrates the whole field in a way to afford insight into needed developments as well as an appraisal of the present situation. It presents the conditions within the schools and much information regarding the entering student, the alumnus, the attitude of practicing engineers, teachers, and industrial managers. It presents a basis for consideration of problems within the engineering school, both undergraduate and graduate, and it shows in illuminating perspective its relations to other fields—the preparatory school, the training courses for gradu-

ates in industry, the technical institute (noncollegiate) the engineering profession, and the economic phases of modern life.

"Both the director of the investigation and the associate director visited most of the engineering schools in this country for information and counsel, thus gaining the intimate knowledge of conditions essential to an evaluation and interpretation of information gathered by other means.

"The director made 2 trips to European countries to visit the engineering schools. The result of these visits form the basis of a perspective comparison of engineering education at home and abroad.

"An important outcome of the general investigation has been the establishing by the Society in 1927 of summer schools for engineering teachers. These schools have brought together each year, for periods of several weeks, nearly a hundred engineering teachers for consideration of better methods of teaching as well as for discussion of the subject matter and the state of the art in their respective fields.

"The findings and preliminary reports of the investigation have been made available immediately through continuous publication in the Society's (S.P.E.E.) monthly ***Journal of Engineering Education***, and in some 20 pamphlet reprints issued as bulletins and reports.

"These are now brought together, revised, and supplemented in the present complete report.

"The contributions by the board and by the staff present summaries, comments, conclusions, and recommendations. Director Wickenden presents in a general report the views of one whose prior career as teacher in engineering schools and as director of educational work in industry, qualifies him to appreciate the problems involved. Professor Hammond, associate director, has had charge of the immediate relations with the engineering schools during the fact-finding period. He has also organized and directed the conduct of the summer schools upon which he has prepared a special report.

"The initial funds for the investigation were provided by a grant from the Carnegie Corporation. These were supplemented by contributions from engineering societies, from industries, and from individuals.

"A supplemental study of technical institutes reveals the status of a neglected field closely related to the collegiate engineering schools and indicates the need of a comprehensive national scheme which will include all branches of technical education. The report of this study is published in this report for the first time in complete form."

Contents of the Summary of Results

In the previously mentioned "Summary of Results," the more important of the numerous bulletins and reports in the complete report are summarized briefly, giving some of the statistical information collected and the conclusions drawn from them. In the "Summary of Results," the following are stated to be among the conclusions reached. (In these excerpts, the superior numerals are references to pages in the complete report.)

"An undergraduate course should equip wholesome and qualified youth with a basic acquaintance with science, familiarity with engineering methods, and an appreciation of social relations.[84] These should be coordinated in time and in content and brought to a focus during the last year upon the student's major subject.[140]

"Three types of activity common to all engineering, for which the undergraduate program should provide a basis, are:[84,1057]

1. The control and utilization of the forces, materials, and energy of nature.
2. The organization of human effort for these purposes.
3. The estimation of costs and appraisal of values, both economic and social, involved in these activities.

An educational process appropriate to these purposes cannot be narrowly technical.

"Engineering education should be a unified process in which scientific, technological, and humanistic studies form an orderly whole; a self contained branch of higher education under unity of supervision.[122] This is in contrast to a divided program having a pre-engineering curriculum under separate administration and a subsequent purely technical curriculum—corresponding to practices in law, medicine, and dentistry.[112,105].

"Engineering education is good general education; it is characterized by a coherent and integral program, unifying an otherwise loose group of studies by professional orientation which becomes increasingly significant in the upper years and dominates the post-graduate period.[85,140]

"Four years, as at present, is the recommended norm for an undergraduate course leading to the bachelor degree. Following present high school graduation this implies a median age of 23 at graduation.[85,138] Students should be at liberty to extend the period to 5 years to include additional subjects or to overcome handicaps in preparation.[139]

"College training should be the foundation for the continued development of the graduate either as a professional engineer, or in other fields, by either of 2 principal methods.[139,1102]

1. By resident graduate study preliminary to his future work, technical and professional or administrative or other.
2. By entrance into practice where experience may be accompanied by continued post scholastic study.

"Engineering education can cope with enlarging responsibility to society and increasing exactions of professional practice by enhancing its own distinctive qualities rather than adding unrelated elements from without. Emphasis on humanistic subjects for enriching the conception of engineering and its place in the social economy, a more connected and better grounding in engineering principles, and greater capacity for self directed work may all be gained at the expense of unrelated studies and detailed training in technique. The latter should find place in postgraduate and post scholastic courses.[140,1048]

"For better engineering education we must look to better balanced curricula, better selection of students, better teachers, better methods, better subject matter, and better advanced training, rather than changes in educational organization.[141,1045]

"For developing teaching personnel each school should have a policy and a definite program covering selection, guidance, engineering experience, and teaching methods. Means may include summer schools for engineering teachers, conferences with engineers and with industry.[106] Engineering schools should provide adequate salaries, and encourage participation of teachers in engineering practice.[107] Teaching loads should not prevent personal development and contributions to engineering progress.[108,1090]

"The board states its views on various matters and offers suggestions. Some of these follow:

1. The credit hours in 4 years should not exceed 144. Simultaneously carried subjects should not exceed 6.[86]
2. The curriculum should be common for all engineering freshmen but for the last year may be widely differentiated; in intermediate years adjusted to local conditions.[86] Options in later years are desirable.
3. Concrete projects, lectures, and conferences should stimulate interest, orient to engineering activities, and serve as a try-out of aptitude.[89]
4. Social and economic studies should reveal the broad interplay of social forces and also the specific economic problems and social situations in the realm of engineering.[90,1048,1156] How to place proper emphasis on engineering economy is an open field for experiment by the engineering colleges. General economics should be taught with consideration for the engineering viewpoint.[91]
5. Specially gifted students should have special programs.[102] Particular programs depend upon sizes of classes and available facilities."

Some of the other conclusions and recommendations, taken from different sections of the "Summary of Results" follow:

"Assistance to high school students in gaining a perspective of engineering as a career may be rendered by conferences, addresses, literature, and moving pictures.[172] Greater discrimination in admission method is advised. Orientation courses in early college years are recommended.[180,183] The report of the board holds that it is a duty of engineering colleges to the profession to attract and admit qualified students, and to reject the undesirable and unfit.[94] . . . a joint agency for co-operation with secondary schools is recommended.[96] Selective admission procedure and subsequent tests[96] are advised."

"Placement examinations (educational tests designed to measure the training and aptitude of the student for subjects commonly included in the first year of engineering curricula) are ineffective in themselves. They furnish the data upon which remedial measures may be based, however, and when administered systematically and discriminatingly they may be of considerable importance in dealing with students."

"Numerous comparisons between graduates of co-operative plans (alternating attendance at school and at work in industry) and other engineering graduates as to positions, earnings, and general progress do not show marked differences. It is concluded that both methods produce equally meritorious results although not of identical character."

"The board advocates graduate work in a few institutions with notable teachers;[117, 123, 146] that this work be open only to proficient students, and that undergraduate study should not be considered as graduate work."

It is pointed out "that the research[320] in many institutions is routine testing rather than scientific investigation; that true research is limited to but few institutions; that the total expenditure is only 5 per cent of that for undergraduate instruction; that this amount is exceeded by each of 4 industrial concerns in their research activities; that the importance of research both for its

immediate results and for the training of men for research justifies increased development and expenditures."

"The need of guidance (of graduates) in the choice of first positions is given emphasis. The means suggested[250] are lectures to seniors outlining various fields; more effective presentation by representatives of industries; personal records of students by colleges."

"Continuation of education after leaving college[252-5] is essential to the graduate; it should be a responsibility of the colleges. Methods proposed are reading courses, correspondence courses, extension courses of various types, advisory services."

A study of the engineering graduate in industry shows that "conclusions[1029] based on statements of graduates and employers are that deficiencies in training are not limited to the engineering college, but involve secondary schools and the educational system as a whole; and that the endeavors of leaders should be: (*a*) in industry, to aid in industrial guidance and in shortening the time for fitting graduates for responsible positions; and (*b*) in the colleges, to develop personality, to give facility in expressing ideas in clear convincing English, and to aid students in choice of positions adapted to their personality and training."

Regarding the cost of education, it is concluded that "the cost per student[345] is much greater in engineering education than liberal arts."

The "situation regarding teaching staffs is quite satisfactory in so far as can be judged by the statistics. But intangibles enter the educational problem.[289] In the selection of teachers,[289-304] administrative officers feel that recruits are not secured from the highest levels of graduates. Adequate salaries, opportunities for engineering practice and for research and scrutiny of all around qualifications are remedial measures. The securing of the right type of teachers[335, 1151] is a major problem in engineering education."

Other subjects discussed in the "Summary of Results" are the need for a national system of technical education, as indicated by a comparative study of engineering education in the United States and Europe; the desirability of summer schools for engineering teachers; a study of technical institutes (noncollegiate); and the relationship between engineering education and the engineering societies.

A Reading List for Junior Engineers

A LIST of books recommended for reading by junior engineers has been prepared by a number of eminent men, many of them distinguished in the engineering profession. Previous sections of this list have been published in ELECTRICAL ENGINEERING for December 1934, page 1667, January 1935, page 133, March 1935, page 345, April 1935, page 456, and May 1935, page 569. The 2 concluding sections are published herewith. The complete list includes more than 100 titles.

Systematic reading of worth while books adds breadth and vision to the background of an engineer and should be considered a part of the intellectual development designed to fit the young engineer for full professional recognition. It is suggested that over a period of about 4 years a minimum of about 25 of these books might be selected and read, with the limiting recommendation that the selection made will include at least one book in each classification, preferably in accord with the individual engineer's most vital interests.

Literature, Including Poetry, Essays, and Fiction

Name and Nature of Poetry, A. E. Housman. Macmillan, 1933. A personal definition of the functions of poetry states that its aims must be to "transmit emotion—not to transmit thought." Nothing on modern poetry.

Oxford Book of English Verse, edited by Sir Arthur Quiller-Couch. Oxford University Press, 1910.

Plays and Sonnets, William Shakespeare.

American Poets, edited by Mark Van Doren. Little, Brown, 1932. Selections from 57 poets from 1630 to 1930.

English Literature, W. N. C. Carlton. American Library Association, 1925. Reading with a Purpose Series.

Enjoyment of Literature, Jay B. Hubbell. Macmillan, 1929.

Essays in Persuasion, J. M. Keynes. Harcourt, Brace, 1932.

Essays of Elia, Charles Lamb.

Marius the Epicurean, Walter Pater.

Emerson's Journals, edited by Bliss Perry. Houghton, Mifflin, 1926.

Thoreau's Journals, edited by Odell Shepard.

Wuthering Heights, Emily Bronte.

The Good Earth, Pearl Buck.

The Way of All Flesh, Samuel Butler.

Lord Jim, Joseph Conrad.

Tale of Two Cities, Charles Dickens.

Brothers Karamasov, Fyodor Dostoievski.

The History of Tom Jones, Henry Fielding.

Forsythe Saga, John Galsworthy.

Growth of the Soil, Knut Hamsun.

Tess of the d'Urbervilles, Thomas Hardy.

Morte d'Arthur, Sir Thomas Malory.

Giants in the Earth, O. E. Rolvaag.

Kidnapped, R. L. Stevenson.

Vanity Fair, William Makepeace Thackeray.

War and Peace, Count Leo Tolstoi.

Ethan Frome, Edith Wharton.

General

Good English, V. C. Bacon. American Library Association, 1928. Reading with a Purpose Series.

The Human Body and Its Care, Morris Fishbein. American Library Association, 1929. Reading with a Purpose Series.

Representative Government, H. J. Ford. Henry Holt, 1924. Three hundred pages of fundamentals by an able journalist who became professor of politics at Princeton through Woodrow Wilson's appreciation of his book on "Rise and Growth of American Politics."

Concise Oxford Dictionary of Current English, Henry W. Fowler. Oxford University Press, 1926. A large amount of information in very little space.

Handbook of English in Engineering Usage, A. C. Howell. Wiley, 1930. Clearly written book for practicing engineers. Promotes proficiency in making up reports, letters, and technical articles and is "a shining example of the principles enunciated."

The Educational Frontier, edited by W. H. Kilpatrick. Century, 1933. A description of a definite program for remedying the confusion existing today in purpose and curriculum of American education.

Education and the Social Crisis, W. H. Kilpatrick. Liveright, 1932. A plea for a study of our "tragically inadequate" system of adult education. Should be read along with Everett Dean Martin's "Civilizing Ourselves."

Public Opinion, Walter Lippmann. Macmillan, 1927. Psychological study and entertaining discussion of the weaknesses of public opinion and the means of influencing it.

Education, Intellectual, Moral, and Physical, Herbert Spencer. Appleton, 1914. Argument for rational scientific education of the body, natural and reasonable moral training, and self activity and interest in intellectual training.

International Congresses to Meet in Europe

Three congresses on engineering subjects are to be held in various parts of Europe during the next few weeks. Arrangements have been made for delegations of Americans to attend each of these congresses.

The first one to meet is the International Electrotechnical Commission, the plenary meetings of which will be held in The Hague and Brussels, Belgium, June 18–27, 1935. Dr. A. E. Kennelly (A'88, M'99, F'13, HM'33, Life Member and past-president) professor emeritus of electrical engineering, Harvard University, Cambridge, Mass., is president of the U.S. national committee of the I.E.C. This committee has made careful preparations for the plenary meetings, and it appears that American electrical industries will be represented by one of the largest and best technically qualified delegations which have been sent abroad in several years.

The second congress is the International Conference on Large High Tension Systems, which will be held in Paris, France, from June 27 to July 6, 1935. The object of this conference, which meets every 2 years, is to study all problems relating to the production, transmission, and distribution of electrical energy. Papers on these subjects are read and discussed, and at the forthcoming session 16 papers are scheduled to be presented by authors from the United States. As in previous sessions, the work will be divided into 3 sections: production and transformation of current; construction, maintenance, and insulation of lines; and operation and protection of systems. The secretary of the U.S. national committee of the International Conference on Large High Tension Systems is Frederic Attwood (M'27), vice president of the Ohio Brass Company, 50 Church St., New York, N. Y.

The third congress is that of the International Commission on Illumination, the

1935 session of which will be held at Berlin, Germany, July 2–5, and at Karlsruhe, July 7–10, 1935. The U.S. national committee, of which G. H. Stickeney (A'04, F'24), consulting engineer for the incandescent lamp department of the General Electric Company, Cleveland, Ohio, has recently been elected president (as announced in this issue, page 687) has been instrumental in insuring a large attendance of American experts in order to provide adequate expression of the viewpoints prevailing in this country.

Of interest also is the meeting of the Societe Belge des Ingenieurs et des Industriels in Brussels, Belgium, June 13–15, 1935, to celebrate the fiftieth anniversary of its foundation. Two Institute representatives have been appointed to attend the celebration.

A.S.T.M. to Revise Copper Wire Specifications

According to reports currently published by the American Society for Testing Materials covering its "committee week" series of meetings held in Philadelphia, Pa., March 4–8, 1935, important revisions were made in the standard specifications for bare concentric-lay copper cable, medium, hard, or soft (*B*8-27). These revisions, reported as providing new requirements for testing this type of copper cable, are scheduled to be referred to the membership of A.S.T.M. committee *B*-1 in the form of a letter ballot. The proposed changes provide for the testing of the cable in its completed form whereas present specifications require tests of the individual wires comprising the cable before, but not after, stranding. Also scheduled for insertion in the new specifications is a new stranding table which seems to have met with the approval of the committee and also with the Insulated Power Cable Engineers Association and the Sectional Committee on Insulated Wires and Cables.

The A.S.T.M. committee also is reported as having received an interesting report of progress from its subcommittee on electrical transmission wire and cable specifications, which report included data resulting from tests made on transmission cable for the purpose of investigating the question of soft versus hard wire core in such cables.

Also, action is reported covering the proposal of tentative additions to the bronze trolley wire specifications to provide requirements covering a trolley wire of higher conductivity than the present 2 classifications. Tentative revisions providing for additional limitations of certain dimensions of grooved trolley wire, both bronze and copper, also were proposed.

Illuminating Engineers to Meet in Cincinnati. The 1935 convention of the Illuminating Engineering Society is to be held at the Hotel Netherland Plaza, Cincinnati, Ohio, September 3–6. A national illumination conference is scheduled for September 3, with the I.E.S. convention following immediately and ending on September 6. A lighting equipment exposition is also being planned.

Franklin Institute Medal Awarded. The Franklin Institute of Philadelphia, Pa., has announced the award for 1935 of a John Price Wetherill Medal, to Robert E. Naumburg, New York, N. Y., for his invention of the visagraph for enabling the blind to read any printed book without the aid of any other person. The award is for "an apparatus original in its accomplishments, and of unquestioned benefit to humanity."

A.S.T.M. Nominates Officers. Nominations for officers to serve the American Society for Testing Materials have been made. H. S. Vassar (A'06, M'18) laboratory engineer, Public Service Electric and Gas Co., Irvington, N. J., has been nominated for president. For vice president, A. E. White, professor of metallurgical engineering and director of the department of engineering research, University of Michigan, Ann Arbor, has been nominated. Members nominated for the executive committee are: W. H. Graves, chief metallurgist, Packard Motor Car Co., Detroit, Mich.; R. L. Hallett, chemist, National Lead Co., Brooklyn, N. Y.; N. L. Mochel, metallurgical engineer, Westinghouse Electric and Manufacturing Co., Lester Station, Philadelphia, Pa.; H. H. Morgan, manager, rail and fastenings department, Robert W. Hunt Co., Chicago, Ill.; and W. R. Webster, chairman of the board, Bridgeport Brass Co., Bridgeport, Conn. Officers elected assume office at the close of the business meeting which will be part of the opening session of the A.S.T.M. annual meeting, June 24–28, 1935, at the Book-Cadillac Hotel, Detroit, Mich.

American Engineering Council

The Federal Work-Relief Bill

American Engineering Council, the "Washington Embassy" of engineers, gives in its news letter of May 15, information on the status of the federal work relief bill. Excerpts from this bulletin follow.

Progress under the work-relief has been delayed during the past month, as the set-up at top has gradually taken form. Actual starting of jobs and hiring of men still awaits the approval of individual projects by the new chain of federal boards which have been placed in control.

The set-up, briefly, starts with a division of application and information, headed by Frank C. Walker, director of the National Emergency Council. Applications for projects are passed from there to an allotment division under Harold L. Ickes. With the President's approval, projects go to a progress division under Harry L. Hopkins who thus is in a key position in the supervision of actual work. Admiral C. J. Peoples, director of treasury procurement, will handle purchase of materials under the Hopkins division. R. G. Tugwell is expected to take over subsistence homesteads and rural community projects. Rural electrification is tentatively under Morris L. Cooke, a member of the American Society of Mechanical Engineers.

Prominent engineers in the higher command include Maj. Gen. Edward M. Markham, chief of engineers; Dr. Elwood Mead, commissioner of reclamation; and Thomas H. MacDonald, chief, Bureau of Public Roads, all on the Works Allotment Division which takes its place in the alphabetical array as "WAD." Fred Schnepfe, director of projects, PWA, has been named secretary. These 4 men are members of the American Society of Civil Engineers.

Two billion dollars are to be released from the works fund, according to present plans, for allocation to projects. This represents half of the 4 billion dollars broken down in the April 15 "News Letter." (See ELECTRICAL ENGINEERING for May 1935, pages 571–2.) Each class of work (highways, rural electrification, etc.) gets, for the present, $^1/_2$ of the sum earmarked in the bill.

General policies stand essentially as stated last month. From recent Presidential statements, it is inferred that relatively small-scale projects, widely scattered, involving a high labor ratio, and possible of completion within a year, will be pushed forward rather than large undertakings, such as dams, where a huge sum would be spent in a restricted area on work which would take several years.

A related item is to the effect that a department of conservation and works is proposed in a bill sponsored by Ickes and introduced by Senator J. Hamilton Lewis of Illinois. This is designed to permit the President to institutionalize on a long-term basis some of the activities which have developed under the emergency units of the government.

Survey of the Engineering Profession

The survey of the engineering profession, by the U.S. Bureau of Labor Statistics in co-operation with Council and the engineering societies, at last goes forward. Heavy pressure of federal work at the Bureau has held up the mailing of the questionnaire forms over the large list of 170,000 names until now, but the final plan is to complete mailing by June 1. The closing date for blanks to be filled in and returned to the Bureau has been set for July 6.

It is essential that returns be complete so that there will be something approaching a census rather than a mere sample. If any professional engineer, or anyone who has qualified as an engineer in the past, fails to receive a questionnaire by about June 10, he is requested to write Andrew Fraser, U.S. Bureau of Labor Statistics, Department of Labor, Washington, D. C., for one of the blanks.

The questionnaires may look formidable but are mainly "yes" and "no" questions which can be checked off in a few minutes. Do it now!

Other A. E. C. Items

Grover C. Loening, a pioneer in aircraft invention and president of the Loening Aeronautical Engineering Corporation, has been appointed chairman of the A. E. C. committee on aeronautics. The purposes of the committee are to encourage civil aviation, promote research, and to sponsor specific improvement such as larger airports, better technical planning of airports, speeding of air services, and co-ordination of Federal and municipal activities. The development of metropolitan air ports was given special stress in a report of A. E. C. to the Federal Aviation Committee, December 1934, the recommendations of which are to be carried forward by Mr. Loening's committee. Mr. Loening has been a prominent figure in aircraft construction and design for more than 20 years. He has contributed many inventions and developments in the aeronautical field, and is the author of books and numerous articles on aviation. He built and flew the first flying boat in 1911, and he invented the first monoplane rigid bracing persuit machine in 1914. He also introduced steel construction.

A study of the civil service system in its relation to engineers will be made by Arthur W. Berresford, past president of A. E. C., who has consented to do this unofficially and to make an informal report as a basis for action by Council. The maintenance of the federal "merit system" is of interest to large numbers of engineers in its relation to salaries, tenure of office, and methods of appointment.

A digest of the Brookings Institution reports entitled "America's Capacity to Produce" and "America's Capacity to Consume" has been prepared by the Maurice and Laura Falk Foundation of Pittsburgh, Pa., through whose courtesy A. E. C. has copies for distribution to engineers who wish to study the results of these basic surveys. Requests will be filled as long as the supply lasts.

Letters to the Editor

CONTRIBUTIONS to these columns are invited from Institute members and subscribers. They should be concise and may deal with technical papers, articles published in previous issues, or other subjects of some general interest and professional importance. ELECTRICAL ENGINEERING will endeavor to publish as many letters as possible, but of necessity reserves the right to publish them in whole or in part, or to reject them entirely.

STATEMENTS in these letters are expressly understood to be made by the writers; publication here in no wise constitutes endorsement or recognition by the American Institute of Electrical Engineers.

Control of Transients in Welding Generators

To the Editor:

The discussion of F. B. Hornby's paper ("Control of Transients in Welding Generators," ELECTRICAL ENGINEERING, volume 53, Dec. 1934, pages 1598–602) by T. M. Linville in the April 1935 issue of ELECTRICAL ENGINEERING, pages 441–4, must be very interesting to all students of arc welding generators. The Hornby machine presumably represents the abandonment by the General Electric Company of the imperfect and, in my opinion, dangerous "transformer reactor" as it has been called, in favor of apparatus which is correctly designed and proportioned according to principles which were made known by myself from 1926 onward as may be seen from my publications.

If we compare the interesting table published by Mr. Linville on page 444 of the April issue with that given by myself in my paper "Performance and Design of Electric Welders with Controlled Transients," A.I.E.E. TRANSACTIONS, volume 52, March 1933, page 274, they appear as in table I. I do not quite follow Mr. Linville's value of $M/\sqrt{L_f + L_w}$ which it seems to me should be 0.077 instead of 0.64.

It will be seen from this that the Hornby machine combines a high inductance in the welding circuit (even higher than I employ though I use an external reactor) with a low inductance in the field circuit (almost exactly the same as mine) which is, of course, correct design, as I have previously pointed out in the literature. For instance, claim 22 of my patent Reissue 19,446 (originally filed in Great Britain 1926) reads as follows:

Claim 22: In combination, an arc welding circuit, and an arc welding generator with falling voltage characteristic connected to supply the welding circuit, said circuit including a high inductance in series with the arc, the generating circuits of said generator including a low inductance field circuit whereby transient effects are materially diminished as compared with those produced when said high inductance in the welding circuit is used with a generator having high inductance generating circuits.

Very truly yours,

F. CREEDY (M'30)
(Prof. of Elec. Engg., University of British Columbia, Vancouver, Can.)

Table I—Comparison of Generators

	Generator "A" Split Pole—Hornby	Creedy
Welding amperes (rated)	400	300
Welding volts (rated)	40	30
Open circuit volts	80	75
Poles	2	8
Rpm	1,785	1,785
Core diameter, inches	10	
Core length, inches	5	
Flux per pole, maxwells	2.6×10^6	
Excitation watts	500	
Self-inductance (henries) of		
Series field winding	0.0120	
Shunt field winding	1.24	
Armature winding	0.0024	
Commutating pole winding	0.0030	
Mutual inductance (henries) between		
Series and shunt field winding	0.084	
Armature and series field winding	0.0003	
Armature and shunt field winding	0.0015	
Armature and comm. pole winding	0.0017	
Total self-inductance of welding circuit (L_w) (very high)	0.0146	.003
Total self-inductance of field circuit (L_f) (very low)	1.24	1.26
Total coupling inductance of field and welding circuits (M)	0.086	0.03
Coefficient of magnetic coupling between the field and the welding circuit (0.077?) ($M/\sqrt{L_f + L_w}$)	0.64	0.027
Total transient inductance of welding circuit ($L_w - M^2/L_f$)	0.0087	0.0023

Similarity Relations in Electrical Engineering

To the Editor:

The paper "Similarity Relations in Electrical Engineering" by J. G. Brainerd and Jacob Neufeld, in the March 1935 issue of ELECTRICAL ENGINEERING, page 268–72, calls attention to a field of mathematics which has not had the proper attention in theoretical investigations in electrical engineering. The first application of the Π-theorem, however, is not correct and leads, by mere chance only, to a correct result. As pointed out by P. W. Bridgeman in his book "Dimensional Analysis," Yale University Press, 1931, dimensional analysis can only be applied in the case of complete dimension systems. Bridgeman gives in his book a number of examples illustrating this point quite definitely. In electromagnetism, 4 fundamental dimensions are required in order to form a complete dimension system; the so-called absolute dimension systems are, therefore, not usable in dimensional analysis. (See "A Proposal to Abolish the Absolute Electrical Unit Systems," by E. Weber, A.I.E.E. TRANSACTIONS, Volume 51, 1932, pages 728–42.) The use of the complete dimension for resistance would have shown at once that an additional quantity is needed in order to establish a relation between the various quantities leading to a dimensional formula. This additional quantity is the permeability which has (even according to the newest decision of the International Electrotechnical Commission, see "Actions on Electric and Magnetic Units," by A. E. Kennelly, ELECTRICAL ENGINEERING 1934, pages 402–5) a dimension and is not a pure numeric. The tabulation of the complete dimensions is as follows:

Resistance	r	$[M][Q]^{-2}[L]^2[T]^{-1}$
Area of cross section	A	$[L]^2$
Frequency	f	$[T]^{-1}$
Permeability	Π	$[M][Q]^{-2}[L]$
Resistivity	ρ	$[M][Q]^{-2}[L]^3[T]^{-1}$

where $[M]$ is the dimension of mass, and $[Q]$ that of electrical charge. From this the dimensional equation results

$$r = A^r f^q \rho^s \Pi^v$$

where s, p, q, and v denote the arbitrary exponents. Inserting the dimensions from

the table above leads to the 4 equations for the 4 fundamental dimensions:

$$[M]: \quad +1 = +s + v$$
$$[Q]: \quad -2 = -2s - 2v$$
$$[L]: \quad +2 = +2p + 3s + v$$
$$[T]: \quad -1 = -q - s.$$

As in the case of the authors, the resistance appears finally in the form

$$r = A^{-1/2+q} \cdot f^q \cdot \rho^{1-q} \cdot \Pi^q = \frac{\rho}{\sqrt{A}} \cdot \left(\frac{Af\Pi}{\rho}\right)^q$$

or

$$\frac{r_{a-c}}{r_{d-c}} = \varphi\left(\frac{Af\Pi}{\rho}\right)$$

which is identical with the form equation 4 of the original paper. With the additional permeability in the dimensional expression, the first of the equations 9 of the authors is obtained which they could not co-ordinate properly; though the authors promise to account for the factor μ used in this equation 9, they fail to do it.

In the paragraph on boundary conditions the authors again make use of the permeability quite arbitrarily. The boundary conditions for the case 2, the case of the "magnetic skin-effect," should be correctly written as follows:

$$H_{T(\text{conductor})} = H_{T(\text{air})}$$
$$(\mu H_N)_{(\text{conductor})} = (\mu H_N)_{\text{air}}$$

It is necessary to take μ into both sides of the equation. In the case of copper and air, for example,

$\mu_{\text{copper}} = 0.999\ 9912$, whereas

$\mu_{\text{air}} = 1.000\ 000\ 38$,

which demonstrates the importance of being exact.

The value of the constant c in equation 6 of the paper is identical with the magnitude of the velocity of light and this is only approximately equal to 3×10^{10} centimeters per second. It does not, however, have the dimensions of velocity but is to be treated as a pure numeric.

Very truly yours,

Ernst Weber (A'31, F'34)
(Research Professor, Dept. of Elec. Engg., Polytechnic Institute of Brooklyn, N. Y.)

Overcompounded Generators in Parallel

To the Editor:

The "compound generators in parallel" series of "Letters to the Editor" promises to rival the grand crescendo of the "square root of A squared plus B squared" series which so firmly held the public interest last year. (Previous "Letters to the Editor" on this subject have appeared in Electrical Engineering as follows: by J. G. Brainerd, volume 51, October 1932, page 745; by O. W. Walter, volume 53, November 1934, pages 1553–4; by J. G. Brainerd, volume 54, January 1935, page 135; by E. H. Nelson and Sidney Rock, volume 54, March 1935, pages 347–8; and by J. O. Reid, volume 54, March 1935, pages 348–9.)

At the risk of boring your readers, I submit the following considerations for your attention:

It has been stated by some, and tacitly assumed by others, that the problem is of purely academic interest. This is hardly the case. The problem is not confined solely to d-c generators but finds application in other fields as well. In ventilation engineering, for example, it is occasionally the practice in large installations to employ 2 medium-sized fans instead of one prohibitively large one, supplying the same duct system (load) in parallel. It is common knowledge among engineers familiar with this field that if the fan characteristics are rising, the motors being ordinary commercial induction motors, there is a possibility of one fan's taking all the load, with a consequent danger of damage of its motor.

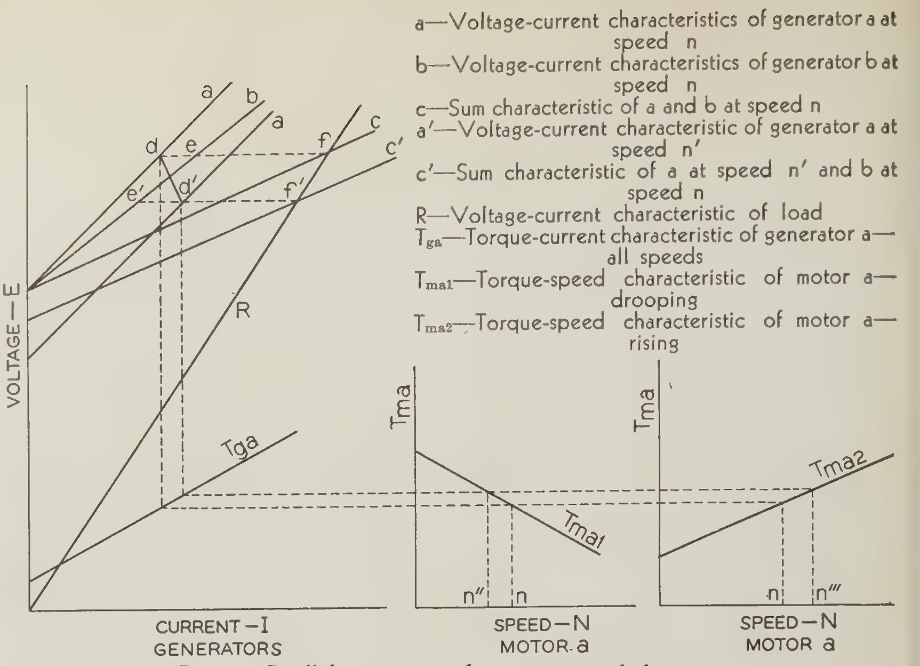


Fig. 1. Parallel operation of overcompounded generators

A somewhat more comprehensive graphical analysis than has hereto been given may be of interest. Several characteristics are shown on the accompanying diagram. For greater ease of construction and interpretation they are shown as straight lines. If desired these lines may be thought of as merely tangent lines to the true characteristics at the points of interest. a and b are the voltage-current characteristics of 2 overcompounded generators operating in parallel without equalizer at the speed n. c is the sum characteristic, and R the load characteristic. Evidently the division of load between the machines and the total load are given by the abscissas of the points d, e, f, respectively. Suppose that for some reason the speed of generator a drops to n', that of b remaining constant. c' is the new sum characteristic, and the division of load and total load are now given by d', e' and f', respectively. The operating point of machine b has passed from e to e'—a decrease of current, voltage, and power—while that of machine a has passed from d to d'—a decrease in voltage but an increase in current and possibly an increase in power, depending upon the slope of d-d' and the positions of these points. Thus, it is clear that the current change depends not alone upon the voltage change, but upon many other considerations.

Evidently the generator which slows down *may* take an increased load, if other conditions are consistent with such a result. To determine whether such a condition will exist in fact, the torque required by this generator and delivered by its motor must be considered. The torque of generator a has increased as shown. Projecting the generator torque-current curve over to the motor torque-speed curve it is seen that in the case of characteristic (1), which is drooping, the greater demand for torque produces a drop in speed, whereas in the second case it produces a speed increase. In the first case, if the slopes of all the characteristics are exactly right, the new motor speed n'' will be equal to n' the postulated new generator speed. (In nature, of course, the slopes of the characteristics determine the speed $n' = n''$ to which the motor-generator a will drop.) In the second case, the new motor speed is greater than the old, whereas a speed drop was postulated. The system, therefore, will not operate in this way and progressive instability is averted. Since in the first case n'' may be equal to n', the behavior depicted is possible. It requires only successive repetitions of the same process to produce a precipitation of the load to the slower machine. A similar construction in which the speed of generator a is assumed to increase shows that here, too, the action may be cumulative only if the torque-speed characteristic of motor a is drooping.

In the above analysis it is assumed that all changes take place so slowly that neither inductance nor inertia has any effect on them. It is felt that the analysis is entirely consistent with the experiments of Dr. Brainerd (Electrical Engineering, volume 51, October 1932, page 745) which proved that this type of instability could occur. (He was careful to point out that he did no more than to show that the phenomenon could take place in at least one case); and of Messrs. Nelson and Rock (Electrical Engineering, volume 54, March 1935, page 348) and in line with the assertions of Dr. Pender which were questioned by Dr. Walter (Electrical Engineering, volume 53, November 1934, page 1553–4.)

A similar situation occurs when generators

with drooping voltage-current characteristics are driven by motors with rising torque-speed characteristics, such as the differentially compounded motor. In this situation the motor generator whose speed *increases* is the one which may take all of the load. The instability is of the same nature as the one under discussion, yet no one, to the writer's knowledge, has been puzzled by it.

Very truly yours,
HARRY C. HART (A'33)
(Penllyn, Pa.)

Operational Calculus

To the Editor:

In a letter, "Operational Calculus," appearing in the December 1934 issue of ELECTRICAL ENGINEERING, page 1681, I. H. Barkey has offered corrections to my paper, "Operational Calculus," in the October 1934 issue of ELECTRICAL ENGINEERING, pages 1339–47. Mr. Barkey gives evidence of having been a student of the historical aspect of operators in general. The field of operators in mathematics is immense. The operational processes which were under discussion in my paper are from only a portion of this field—a portion which can be particularly helpful to engineers interested in the analysis of transient vibrations, waves, and diffusion in linear systems. It is regrettable that the title of the paper did not adequately disclose this restriction, but the point was made in the subject matter that attention was directed primarily to operational methods such as employed so boldly and practically by Heaviside in connection with step functions. Because he has been unmindful of this restriction of field, Mr. Barkey has cited references which are not of moment to the engineer in this connection.

Operational processes which in *form* are the same as those Heaviside used do appear extensively in early mathematical literature, but their application is to functions which are analytic in the region of interest, i. e., functions which can be developed in a power series which is convergent in this region. One wishing to delve into the early history of operational or symbolic methods in general, which have been used in differential and integral calculus and in differential equations, should consult "Symbolic Calculus. Bibliography on General (or Fractional) Differentiation," by E. Stephens, Washington University Studies, volume 12, *Scientific Series*, number 2 (1925), pages 137–52.

Heaviside was interested in the application of operational processes to nonanalytic functions, such as his unit function. In this his work was heuristic, but it was subsequently substantiated and shown to be but a formal expression of the processes of the Laplacian transformation. Some helpful references, less widely known but bearing upon this, are given at the end of this letter. For the form of the Laplacian transformation—hereafter abbreviated L-transformation—see equation 21 of my paper. By means of it a set of dissociated rules of procedure has been replaced by a method highly systematic in its application and capable of being made as rigorous as desired. With the advantage of its philosophy, one not only understands why the Heaviside type of operational calculus proceeded as it did, but visualizes extensions along lines the seeds for development of which were hardly apparent in the Heaviside form.

This L-transform type of operational calculus facilitates the solution of linear differential, integro-differential, and difference equations. Certain restricted nonlinear applications have been made. See "Verallgemeinerte Laplacesche Integrale als Lösungen linearer und nichtlinearer Differentialgleichungen" by J. Horn, *Jahr. der Deut. Math. Ver.*, volume 25, 1917, pages 301–25, and earlier papers by the same author referred to there. While nonlinear problems can be formulated in terms of L-transforms, the process involves convolution in the complex domain, results in integral equations, and does not seem to simplify the solution. So in my paper the emphasis upon linearity was made advisedly.

The discussion was not upon mathematical operators in general, but upon the particular differential operators arising from linear differential equations. These operators *are* treated as ordinary algebraic elements, and the justification for this comes solely from the L-transform.

It is not stated that Boole was the first to use the operator D.

The question is not who was the first to use a partial fraction expansion in any way, but rather who used it first in solving differential equations. Mr. Barkey's comments here fall short of the mark. He has overlooked the important contributions of Cauchy, such as his "Mémoire sur le calcul intégral," *Oeuvres*, series 1, tome 2, pages 195–328, written in 1824, some 13 years before Lobatto's publication which is cited. Here Cauchy used partial fraction expansions, showed the relationship of the symbolic calculus to the Fourier integral, and solved the problem with general boundary conditions. His solution will be sketched briefly, as it discloses his thorough insight into the symbolic method of calculation years before Heaviside's time.

Starting with the linear differential equation with constant coefficients expressed in symbolic form (page 217, *loc. cit.*), and using the symbols as found there,

$$F(\alpha)u = f(t)$$

where α is the time differentiator $\frac{d}{dt}$ and enters only in positive integral powers, u is the unknown function of t, and $f(t)$ is the disturbing force function; the formal operational solution for u is made, giving

$$u = \frac{f(t)}{F(\alpha)}$$

By treating α as an algebraic element, $F(\alpha)$ is written as a product of linear factors

$$F(\alpha) = A_n(\alpha - \theta_0)(\alpha - \theta_1)\ldots.(\alpha - \theta_{n-1})$$

where A_n is the coefficient of the highest derivative of u in the original differential equation. The partial fraction expansion of the operational solution gives

$$\frac{f(t)}{F(\alpha)} = \frac{1}{F'(\theta_0)}\,\frac{f(t)}{\alpha - \theta_0} + \frac{1}{F'(\theta_1)}\,\frac{f(t)}{\alpha - \theta_1} + \ldots + \frac{1}{F'(\theta_{n-1})}\,\frac{f(t)}{\alpha - \theta_{n-1}}$$

By means of the Fourier double integral, each term of this sum is shown to have a solution of the form

$$\frac{1}{F'(\theta_0)}\,\frac{f(t)}{\alpha - \theta_0} = \frac{1}{F'(\theta_0)}\,\epsilon^{\theta_0 t}\int \epsilon^{-\theta_0 T} f(T)dT$$

The indefinite integral is replaced, with equal generality. by the definite integral and a constant C_0.

$$\frac{1}{F'(\theta_0)}\,\frac{f(t)}{\alpha - \theta_0} = \frac{1}{F'(\theta_0)}\,\epsilon^{\theta_0 t} \times \left[C_0 + \int_0^t \epsilon^{-\theta_0 T} f(T)dT\right]$$

This C_0 with similar constants entering from each of the other terms in the partial fraction sum provide the necessary arbitrary constants, enabling one to make the solution fit the boundary conditions.

When Heaviside considered this problem, he recognized the practical importance of treating a simple boundary state of initial equilibrium, and a simple disturbing force function $\mathbf{1}(t)$. It is well known that the stipulation of initial equilibrium is the same as saying the initial value of the dependent variable u and its first $n-1$ derivatives are to be zero at $t = 0$, and consequently that all arbitrary constants, such as C_0, must be zero. The result of each term in the partial fraction expansion under these conditions becomes

$$\frac{1}{F'(\theta_0)}\,\frac{\mathbf{1}(t)}{\alpha - \theta_0} = \frac{1}{F'(\theta_0)}\,\epsilon^{\theta_0 t}\int_0^t \epsilon^{-\theta_0 T}\mathbf{1}(T)dT$$

This integration, when carried out for each of the terms of the sum, gives the result which is known conventionally as the Heaviside partial-fraction expansion theorem. Heaviside, by interesting himself in a special case, arrived at a result which was latent in the literature at least 60 years prior to his writing.

In view of the treatment of this problem by means of L-transforms, wherein the initial conditions of the system may be entirely general, it is interesting to note that even this is anticipated by Cauchy. In his mémoire "Sur la détermination des constantes arbitraires renfermees dans les intégrales des équations différentielles linéaires," *Oeuvres*, series 2, tome 7, pages 40–54, he gives a process in which the arbitrary constants of the solution are written directly in terms of prescribed boundary values. The transform theory can do no more, although it makes the whole procedure more direct and easier to understand.

The above may be applied further to correct Mr. Barkey's remarks in regard to what the distinguishing features of the Heaviside type of operational calculus are. In addition to the use of the unit function, the important feature is the restriction of boundary conditions to those of equilibrium. It is as a *consequence* of this restriction that the inverse operator p^{-1} means integration between limits zero and t.

In Mr. Barkey's integral interpretation of p^{-1} he indicates that it is necessary to approach the lower limit from the positive side. The possibility of a discontinuity at the origin is apparently a matter of concern to him, whereas the possibility of a finite number of additional discontinuities thereafter is entirely overlooked, and such may well occur. Integration in a Riemann sense is involved; there is no need for the limit process which his notation suggests.

Contrary to Mr. Barkey's assertion, Heaviside did give on page 36, "Electromagnetic Theory," volume 2, an "explicit evaluation" of his unit function as

$$\mathbf{1}(t) = \begin{cases} 0 & t < 0 \\ 1 & 0 < t \end{cases}$$

No doubt Mr. Barkey meant Heaviside gave no *other* representation. Furthermore, his statement regarding "the necessary and sufficient conditions under which" this function can have a certain representation is meaningless.

The D operational theorems

$$\epsilon^{hD}F(t) = F(t + h)$$

$$\phi_0(D)\{\phi_1(t)\phi_2(t)\} = \phi_1(t + D_0)\phi_0(D_2)\phi_2(t)$$

employed by Mr. Barkey need comment. Using the singly infinite L-transform, such as given in equation 21 of my paper, the first with h positive is invalid when used with nonanalytic functions, such as involved in his argument, unless $F(t) = 0$ for $0 < t < h$. It is a common mistake to bring over this old theorem, good for analytic functions, into the treatment of nonanalytic functions without any attention to its limitations. The transform theory is of greatest assistance in providing guidance here. The second theorem I neither recognize nor understand.

The solution for $i(t)$ which Mr. Barkey gives is far from recognizable as "the solution of the Heaviside problem as substantially given by Bromwich, and his disciple, H. Jeffreys." A study of the writings of these 2 would never disclose any substantial resemblance between the transform for $\phi(t)\mathbf{1}(t)$ as they would have written it and the $\dfrac{\phi(t + D\nu)}{\nu}$ which Mr. Barkey writes in the integrand.

Despite the eminent sources of the equation

$$\frac{1}{p} f(t) = \int_0^\infty \epsilon^{-px} f(x)\, dx = \int_0^t f(x) dx$$

presented by Mr. Barkey, it does not stand up under examination. It is an example of the confusion which vitiates the reasoning in this subject when the symbol p is used indiscriminately as an operator and as a complex variable. The middle member is the L-transformation. In it the symbol p is a complex variable. When this integral is evaluated, the result is the L-transform of $f(x)$, and is a function of the complex variable p. Violating the meaning of equality, the left member is an operational expression in which p is a symbol of operation, the right member is a definite integral which when evaluated gives a function of t. There is consistency between left and right members, but each is inconsistent with the middle member.

The final equation in his discussion is similarly confused. On the right is the L-transform of $i(t)$, which is a function of the complex variable p; on the left is an operational expression in p and 2 functions of the real variable t, resulting presumably in a function of t.

Mr. Barkey attempts to prove that Heaviside knew the direct L-transformation, and that this relationship was not due to Carson. It must be admitted that this transformation has been in the mathematical literature since 1785; see, for example, page 280 of Laplace's "Mémoire sur les approximations des formules qui sont fonctions de très grands nombres," *Oeuvres complètes*, volume 10, pages 209–338. Cauchy used it; see, for example, equation 13, page 148, of his "Sur la transformation des fonctions d'une seule variable en intégrales doubles," *Oeuvres*, series 2, tome 7. Of the many writers who have employed it as a means of substantiating Heaviside's methods, probably the first was Giorgi. See his "Sul Calcolo delle Soluzioni Funzionali," *Associazione Elettrotecnica Italiana Atti*, volume 9, 1905, pages 651–99, or his 1924 paper in English cited below.

In appraising the applicational success of the L-*integral* equation, Mr. Barkey does not seem to appreciate that the solution of this integral equation is given in all cases by the inverse L-transform. (See remarks relative to equations 24 and 25 in my paper.) This explicit solution in the form of a line integral in the complex plane of course may not be easy to evaluate in particular cases.

In conclusion, let me emphasize again that the trend of developments in this subject is distinctly away from formal symbolic methods toward the rigorous methods of transform theory—a situation which Mr. Barkey apparently does not appreciate; otherwise, it is unlikely that he would be approaching the subject in the manner in which he does. One will gain much insight into this development from papers such as the following:

ON THE FUNCTIONAL DEPENDENCE OF PHYSICAL VARIABLES, G. Giorgi. *Proc.*, International Math. Congress, Toronto, 1924, v. 2 p. 31–56.

HEAVISIDE'S OPERATIONAL METHOD, D. P. Dalzell. *Proc.* Phy. Soc., London, v. 42, 1928–30, p. 41–2.

OPERATIONSKALKÜL VON HEAVISIDE UND LAPLACIAN TRANSFORMATION, T. Von Stachó. R. Univ. Hung. *Tran.-Jo.*, Szeged, Octa, 3, p. 107–20.

ÜBERLICH ÜBER GEGENSTAND UND METHODE DER FUNKTIONAL ANALYSIS, G. Doetsch. *Jahresber.* Deutsch. Math. Ver., v. 36, 1927, p. 1–30.

DIE ANWENDUNG VON FUNKTIONALTRANSFORMATIONEN IN DER THEORIE DER DIFFERENTIALGLEICHUNGEN UND DIE SYMBOLISCHE METHODE (OPERATORENKALKÜL), G. Doetsch. *Jahresber.* Deutsch. Math. Ver., v. 43, 1934, p. 238–51.

I am appreciative of the help given me by Dr. J. L. Barnes, of the department of electrical engineering, Massachusetts Institute of Technology.

Very truly yours,

M. F. GARDNER (M'31)
(Assistant Professor, Massachusetts Institute of Technology)

Personal Items

V. J. F. BRAIN (A'22, M'32, and local honorary secretary) chief electrical engineer, Department of Public Works, Sydney, Australia, has been installed as chairman of the Sydney division of the Institution of Electrical Engineers, Australia. Mr. Brain graduated from Sydney University in 1922, after which he came to the United States, where he was connected with the General Electric Company at Schenectady, N. Y., and for a short time with the Alabama Power Company. In 1925 he entered the New York Edison Company, New York, N. Y., as assistant engineer in the electrical engineering department, where he remained until 1929, when he was appointed to his present position. Mr. Brain was a member of the Institute's committee on protective devices during 1928–29.

J. W. COWLES (A'02, M'03) since 1913 superintendent of the installation department, Edison Electric Illuminating Company of Boston, Mass., has retired from active service. Mr. Cowles was born at Norfolk, Conn., and was graduated from the electrical engineering course at Cornell University in 1890. Until 1893 he was with the Thomson-Houston Electric Company at Lynn, Mass., and after short periods of time as assistant city engineer at Malden, Mass., and with the Marks-Ayer Electric Company, New York, N. Y., joined the Boston Electric Light Company in 1895. Following the consolidation of this company with the Edison company in 1901 he became assistant head of the standardizing and testing laboratory, and the following year was appointed superintendent of distribution. Mr. Cowles served on the lighting and illumination committee (now committee on production and application of light) of the Institute during the period 1914–16.

BURKEWOOD WELBOURN (M'26) chief engineer, British Insulated Cables, Ltd., Prescot, England, has been awarded the honorary degree of master of engineering from the University of Liverpool. Presentation will be made in July 1935. Mr. Welbourn studied at King's College, London, and after a few years of employment entered British Insulated Cables, Ltd., in 1897 as an assistant engineer. In 1901 he became chief construction engineer, and since 1927 has been chief engineer. Mr. Welbourn is a past vice president and at present a member of the council of the Institution of Electrical Engineers (Great Britain) and a past chairman of its Liverpool Centre. He has been a member since its inception of the advisory committee of engineers to the electrical department at Liverpool University.

K. B. MCEACHRON (A'14, M'20) research engineer of the General Electric Company at Pittsfield, Mass., has been awarded the Edward Longstreth medal of the Franklin Institute. Presentation was made on May 15, 1935. The award was established in 1890 for the "encouragement of invention, and in recognition of meritorious work in science and the industrial arts," and the official citation reads: "In consideration of

his careful conduct of a series of closely controlled investigations extending over a period of 6 years which resulted in the successful development of a process for the manufacture of thyrite." This material is used for a number of applications, principally lightning arresters. Mr. McEachron has been with the General Electric Company for 13 years, and since 1933 has been in charge of the high voltage laboratory at Pittsfield. He has been a member of the Institute's protective devices committee since 1933, serving previously on this committee 1926–28 and on the electrophysics committee 1926–32. Mr. McEachron has presented a number of papers before the Institute on the subject of lightning.

P. G. Burton (A'95, M'13, F'16, and member for life) general plant manager, Chesapeake and Potomac Telephone Company, Washington, D. C., has retired from active work after 41 years with the Bell System. Mr. Burton studied at Cornell University, but left because of illness. After 3 years in electrical contracting work he became connected with the Western Electric Company at New York, N. Y., becoming assistant superintendent of the installation department in 1900. In 1904 he accepted the position of superintendent of maintenance with the Chesapeake and Potomac Telephone Company, and the following year was appointed plant superintendent of the Washington division. He was appointed engineer of this and associated companies in 1912, and in 1920 was appointed general superintendent of plant, becoming general plant superintendent in 1927, the title being changed 2 years later to general plant manager. Mr. Burton was at one time chairman of the Washington, D. C., Section of the Institute, and presented several papers at Section meetings. He is a charter member of the Alexander Graham Bell chapter of the Telephone Pioneers.

Henry E. Warren (A'02) president of the Warren Telechron Clock Company, Ashland, Mass., has been presented with a John Price Wetherill medal of the Franklin Institute in recognition of his invention of the "telechron" clock motor. The John Price Wetherill medal, inaugurated in 1925, is of silver, and is awarded for discovery, invention, or development in physical sciences. Mr. Warren recently was awarded the Lamme medal of the A.I.E.E., presentation of which will be made at the summer convention at Ithaca, N. Y. A biographical sketch and photograph of Mr. Warren appear on page 351 of Electrical Engineering for March 1935.

L. F. Morehouse (M'16, F'20, and past vice president) who since 1933 has been assistant director of system development for the Bell Telephone Laboratories, Inc., New York, N. Y., is now in London, England, where he is technical representative in Europe for the American Telephone and Telegraph Company and the Bell Telephone Laboratories, Inc. He is succeeding H. E. Shreeve (A'07, F'30) who is planning to retire. Mr. Morehouse, a graduate of the University of Michigan, entered the Western Electric Company in London as transmission engineer in 1906 after several years of teaching electrical engineering. Three years later he became equipment engineer with the American Telephone and Telegraph Company at New York, and from 1919 to 1933 held the position of equipment development engineer. Mr. Morehouse was a manager of the Institute 1919–23 and a vice president 1924–26, and has been very active in committee work. He is the author of an Institute paper on machine switching for telephones.

G. H. Stickney (A'04, F'24) consulting engineer, incandescent lamp department, General Electric Company, Cleveland, Ohio, has been elected president of the U. S. National Committee of the International Commission on Illumination. He succeeds E. C. Crittenden (A'19, M'22) assistant director, National Bureau of Standards, Washington, D. C., who resigned after 7 years as president in order that the U. S. delegation to the forthcoming sessions of the commission in Germany might be headed by its president, Mr. Crittenden not being able to leave the country at this time. Mr. Stickney has been with the General Electric

G. H. STICKNEY

Company since 1896, when he entered the student course. In 1909 he became assistant director of the illuminating engineering laboratory at Schenectady, N. Y., and 2 years later went to Harrison, N. J., where he became head of the lighting service department. Mr. Stickney was president of the Illuminating Engineering Society 1917–18, and has served on several Institute committees. He has been a member of the standards committee since 1923, and served on the committee on the production and application of light 1919–33, being chairman 1921–25. He is a fellow of the American Association for the Advancement of Science.

M. K. Goldstein (A'33) formerly with the J. D. Radio Company, Baltimore, Md., and with the U.S. Navy aerodynamical laboratory, is now engineer in charge of the electronics department of the Molded Insulation Company, Philadelphia, Pa. Doctor Goldstein has been engaged in research on multiplex vacuum tubes and color music transmission and reproduction, and is now developing an automatic remote indicating system for anti-aircraft gun control apparatus. The 1933 A.I.E.E. Middle Eastern District prize for best paper was awarded to him for his paper "Telemetering in Large Power Stations." A biographical sketch and photograph of Doctor Goldstein appear on page 1683 of Electrical Engineering for December 1934.

F. M. Farmer (A'02, F'13) vice president, chief engineer, and director, Electrical Testing Laboratories, New York, N. Y., has been nominated as Institute representative on the Engineering Foundation board. Mr. Farmer is vice chairman of the standards council of the American Standards Association, and is chairman of the Institute's committee on research and a member of the committees on power transmission and distribution, co-ordination of Institute activities, technical program, executive, standards, award of Institute prizes, and Edison medal.

J. S. Murray (A'21, M'31) electrical engineer, Follansbee Brothers Company, Follansbee, W. Va., has recently been appointed manager of the electrical sheet department on sales and production. He will also continue to serve as electrical engineer, the position he has held since 1919. Mr. Murray is also a member of the American Society for Testing Materials and the Association of Iron and Steel Electrical Engineers, and served on the Institute's committee on applications to iron and steel production 1932–34.

T. H. Haines (A'23, M'31) superintendent of distribution, Edison Electrical Illuminating Company of Boston, Mass., has had his jurisdiction enlarged to include the installation department, the departments being merged following the retirement of J. W. Cowles (A'02, M'03) from active service. Mr. Haines has been with the company since 1913, and became superintendent of distribution in 1925. He is a member of the Institute's committee on power transmission and distribution, on which he has served since 1931.

J. B. MacNeill (A'18) general manager of distribution engineering, Westinghouse Electric and Manufacturing Company, who has been at East Pittsburgh, Pa., is now at Boston, Mass. Mr. MacNeill has been a member of the Institute's power transmission and distribution committee since 1933, and was a member of the protective devices committee 1920–22 and 1928–32. He has contributed several papers on circuit breakers to the Institute.

J. B. Whitehead (A'00, M'08, F'12, Life Member, and junior past-president) has been nominated as a representative of the Institute on the division of engineering and industrial research, National Research Council. Doctor Whitehead is now a member of the Institute's executive, electrophysics, Edison medal, and Institute policy committees, and is serving on the John Fritz medal board of award.

F. B. Jewett (A'03, M'10, F'12, and past-president) vice president of the American Telephone and Telegraph Company and president of the Bell Telephone Laboratories, New York, N. Y., has been appointed to a special service board of 8 scientists and engineering experts to investigate lighter-than-air craft, the future of which in the United States will be determined largely by the board's recommendations. The committee was appointed by K. T. Compton (F'31) president of Massachusetts Institute of Technology and chairman of the Navy's science advisory board.

W. M. Dann (A'04, F'26) assistant manager, Westinghouse Electric and Manufacturing Company, Sharon, Pa., has been appointed alternate representative of the Institute on the sectional committee on transformers. Mr. Dann is a member of the Institute's membership committee, and served on the electrical machinery committee 1924–31.

K. W. Jarvis (A'25, M'34) formerly assistant chief engineer, Zenith Radio Corporation, Chicago, Ill., is now eastern division general manager for the Meissner Manufacturing Company, New York, N. Y. Mr. Jarvis has been active on committees of the Institute of Radio Engineers, and is the author of a number of papers, published principally in the I.R.E. *Proceedings*.

Kennard Pinder (A'28) electrical engineer, E. I. du Pont de Nemours and Company, is now in the engineering department at Wilmington, Del. Since 1933 he had been at Waynesboro, Va., where he was in charge of all electrical design and electrical construction for the Du Pont Rayon Company during the building of a new plant.

J. E. Borland (A'22) who has been a general engineer with the Westinghouse Electric and Manufacturing Company at East Pittsburgh, Pa., is now with the Westinghouse Electric Company of South Africa, Ltd., at Johannesburg. Mr. Borland has been a member of the Institute's committee on applications to mining work since 1933.

G. M. Palo (A'32) formerly with the General Electric Company at Erie, Pa., is now assistant chief water heating inspector with the Puget Sound Power and Light Company, Seattle, Washington. An article by him on water heating has appeared in technical publications.

R. E. Lyle (A'32) is now an electrical engineer at the engineering experiment station of Washington State College, Pullman. He recently conducted a survey of electric heating in the Columbia basin with the contractors camp at Mason City as a laboratory.

K. V. Condon (A'31) has resigned as superintendent of the Bolivian Power Company, La Paz, Bolivia, South America, and has entered business as a contractor for hydroelectric and allied construction, acting also in an advisory capacity for Fabulosa Mines Consolidated, La Paz.

William Webber (A'33) who has been connected with the Royal Dutch-Shell Oil Company at Mexico, Federal District, Mexico, is now in the engineering department of The Flintkote Company at Chicago Heights, Ill.

Jose Aguado (A'34) assistant to general manager, Armstrong Cork Products Company, who has been at Lancaster, Pa., is now at Cincinnati, Ohio. He has been engaged in organizing branches and in sales force training and has been traveling extensively.

Harold Egeberg (A'28) resigned as inspecting engineer with the Queensland Insurance Company, Ltd., Brisbane, Queensland, Australia, and is now assistant electrical engineer with the Department of Public Works, Queensland.

H. F. Boe (M'30) manager at Buffalo, N. Y., for the Westinghouse Electric and Manufacturing Company, has been promoted to the position of assistant manager of the eastern district, with headquarters at New York, N. Y.

E. F. Beck (M'35) chief engineer, Westinghouse X-Ray Company, Inc., Long Island City, N. Y., has been appointed one of the Institute's representatives on the sectional committee on safety code for lightning protection.

A. B. Lambert (A'31, M'32) who has been sales engineer with Bepco Canada Limited, Toronto, Ont., is now at Manchester, England, having rejoined the sales engineering staff of Crompton-Parkinson Limited.

S. W. Dana (A'33) formerly with the International Business Machines Corporation at Pittsburgh, Pa., is now in the distribution department of the Potomac Electric Light and Power Company, Washington, D. C.

W. F. Grauch (A'34) formerly with the Olean, N. Y., office of the Dresser Manufacturing Company of Bradford, Pa., is now with the Niagara, Lockport and Ontario Power Company and is at Batavia, N. Y.

A. J. Kohler (A'04) former appraisal engineer in the gas valuation bureau of the Public Utilities Commission of District of Columbia, Wash., is now engineer inspector, Public Works Administration, Elmira Reformatory, Elmira, N. Y.

A. E. Saldana (A'33) former engineer in the construction department, Cia. Colombiana de Electricidad, Barranquilla, Columbia, South America, is now with the Porto Rico Railway Light and Power Company, San Juan.

W. A. Barnes (A'24) who has been chief engineer of The Swartzbaugh Manufacturing Company at Toledo, Ohio, has accepted the position of chief engineer with The Dominion Electrical Manufacturing Company which is now located at Mansfield, Ohio.

F. S. Giller (A'13, M'25) former assistant general purchasing manager for the International Standard Electric Corporation, London, England, has engaged in private practice as an international business consultant at Hextable.

A. H. Brolly (A'27) engineer, Television Laboratories Ltd., who was at San Francisco, Calif., is now at Philadelphia, Pa. Mr. Brolly is the author of a paper on television published in Electrical Engineering in August 1934.

L. F. Griffith (M'33) former engineer in the distribution department of the Shanghai Power Company, Shanghai, China, is now employed as an engineer by the U.S. Government at Washington, D. C.

W. F. Laubscher (A'27) who has been at Florence, Ala., in connection with the Wilson Dam, is now at Chattanooga, Tenn., in the department of electricity of the Tennessee Valley Authority.

Robert McDonald (A'29) Cerro de Pasco Copper Corporation, who recently was with the hydroelectric department at La Oroya, Peru, South America, is now at Malpaso, Peru, as chief electrician.

P. O. Bobo (A'33) formerly a draftsman with the Oklahoma State Highway Department, Oklahoma City, is now in the relay department of the Oklahoma Gas and Electric Company, Oklahoma City.

J. A. Fizzell (A'34) formerly with the Standard Electrical Instrument Laboratories, Kansas City, Mo., is now in the research department of the Illinois Testing Laboratories, Chicago.

W. W. Brooks (A'34) who has been field engineer for the Illinois Water Survey at Mason City is now research assistant in electrical engineering at the University of Illinois, Urbana.

J. M. Stock (A'31) formerly with the Cia de Electricidad del Sud Argentino, Buenos Aires, is now employed by the Yorkshire Electric Power Company, Southampton, England.

C. H. Kenny (M'25) former chief engineer of Bart Laboratories, Belleville, N. J., is now an electrical engineer with the Public Service Commission of the State of New York, and is located at New York City.

H. H. Ehrenburg (A'28) former city electrical engineer, Rotterdam, Holland, has taken the position of manager of the Twentsch centraal station for the Electrische Stroomlevering at Hengelo.

H. F. Kingdon (A'26) former design engineer, Canadian Crocker-Wheeler Company, Ltd., St. Catherines, Ont., Can., is now with the Commonwealth Electric Corporation, Ltd., at Welland, Ont.

C. C. CAMPBELL (A'24) former assistant engineer, Pacific Gas and Electric Company, San Francisco, Calif., has engaged in the automobile service and accessory business at Truckee, Calif.

R. J. PHILIPPS (A'34) former designing engineer with Kenyon Transformer Company, New York, N. Y., is at Bristol, Pa., as electrical engineer and plant superintendent for Fleetwings, Inc.

G. C. SHARMA (A'24) former principal of the Victoria Diamond Jubilee Hindu Technical Institute, Lahore, India, is now technical representative for the Tide Water Oil Company (India) Ltd., Lahore.

P. K. MOFFATT (A'25) who has been with the Cia. Cubana d' Electricidad, Havana, Cuba, is now with the Potomac Electric Power Company, Washington, D. C., as cable engineer.

T. J. BURRIN (A'34) formerly in the engineering department of the Public Service Commission of Indiana, Indianapolis, has been appointed superintendent of the utilities department of Lebanon, Ind.

M. K. TOEPPEN (A'21, M'21) Lansing, Mich., has resigned as chief consulting engineer of the Michigan Public Utilities Commission. Mr. Toeppen has been with the commission since 1920.

R. J. WENSLEY (A'28) formerly a division engineer with the Westinghouse Electric and Manufacturing Company at Newark, N. J., is now with the I-T-E Circuit Breaker Company at Philadelphia, Pa.

E. W. THORNCROFT (A'31) former resident electrical engineer, Sutherland Shire Council, Sutherland, New South Wales, Australia, is now with Essantee Switchgear Limited, Sydney, Australia.

G. A. BOOTH (A'13) former local manager at Mukden, Manchuria, for Andersen, Meyer and Company, Ltd., is now manager at Tientsin, China.

ONEY EVANS (A'34) of Uvalde, Tex., is now with the Lago Oil and Transport Company, Ltd., at Aruba, Dutch West Indies.

D. J. CORRIGAN (A'34) of Sunrise, Wyo., is now electrical power survey engineer for the State of Wyoming, Cheyenne.

R. C. CARLSON (A'34) of Ludlow, Pa., is now a student engineer with International Business Machines Corporation, Endicott, N. Y.

WEBSTER RICHARDSON (A'34) Cleveland, Ohio, is now an engineer in the house heating department of the East Ohio Gas Company, Cleveland.

G. J. SCHOTTLER (A'25) former patent lawyer with Emery, Booth, Varney, and Whittemore, New York, N. Y., is now with the General Cable Corporation, New York.

FORTUNATO BAZZEGHIN (A'22) former electrical draftsman with Thomas E. Murray, Inc., New York, N. Y., is now with the American Brake Shoe and Foundry Company, Mahwah, N. J.

J. D. HARPER (A'34) junior electrical engineer with the Aluminum Company of America, who has been at Tapoco, N. C., is now at Alcoa Tenn.

A. J. HUGHES, JR. (A'33) of Fountain Inn., S. C., is now with the emergency crop loan office of the U.S. Farm Credit Administration at Memphis, Tenn.

B. E. YUSIM (A'30) Amtorg Trading Corporation, New York, N. Y., has returned to New York from Moscow, U.S.S.R., after 3 years in Russia.

R. L. DAELEY (A'34) of Streamstown, Alberta, Can., is now Canadian representative of the Helwig Company at Vancouver, B. C.

K. M. JOEHNK (A'34) General Electric Company, who has been in the testing department at Schenectady, N. Y., is now at Bridgeport, Conn.

A. B. NOMANN (A'32) of South Pasadena, Calif., is now employed as a foreman in the instrument shop of the U.S. Coast and Geodetic Survey at Pasadena.

J. L. TONGE (A'31) former consulting architect at Cranston, R. I., is now a valuation engineer with M. E. Scharff, New York, N. Y.

E. S. STEINBACH (A'09, M'22) industrial engineer, Stone and Webster Engineering Corporation, who has been at Boston, Mass., is now at St. Louis, Mo.

J. A. POLLAK (A'33) who has been in the U.S. Engineer's Office at Cape Girardeau, Mo., is now at St. Louis as a student engineer.

W. S. FINLAY, Jr. (A'18, F'21) president, The West Penn Electric Company, who has been at Pittsburgh, Pa., now has his offices at New York, N. Y.

C. F. MYERS (A'31) Puget Sound Power and Light Company, who has been at Wenatchee, Wash., is now distribution engineer at Everett, Wash.

G. W. KEMPER (A'31) of Wapello, Iowa, is now in the test department of the Westinghouse Electric and Manufacturing Company at Sharon, Pa.

J. M. MORGAN (A'22, M'30) former rural electrification engineer, State of South Carolina, Columbia, is now with the Federal Power Commission, Washington, D. C.

I. M. DOW (A'27) Washington, D. C., is now an assistant engineer in the ordnance design division of the U.S. Navy Department.

R. E. REID (A'12) engineer formerly with the La Grange Gold Dredging Company, La Grange, Calif., is now with the Capital Dredging Company at Folsom City, Calif.

E. F. ADAMS (A'33) Elizabeth, N. J., is now an electrical engineer with the Weston Electrical Instrument Company, Newark, N. J.

C. A. ROSENCRANS (A'33) of Warwick, N. Y., is now a student engineer with R.C.A. Victor Company, Camden, N. J.

R. B. ZANE (A'34) The Okonite Company, who has been at Passaic, N. J., as a research engineer, is now in Chicago, Ill.

J. B. FOUNTAIN (A'35) division engineer Mississippi Power and Light Company, has been transferred from Greenville to Jackson.

TETSUJIRO YOKOTA (A'19) formerly at Kobe, Japan, is now with the Mitsubishi Electric Company at Nagoya.

A. W. BECHLEM (A'25) of Syracuse, N. Y., is now an engineer with The Solvay Process Company at Baton Rouge, La.

J. T. MULLEN (A'29) plant chief, Indiana Bell Telephone Company, who has been at Marion is now at Evansville.

A. B. COHEN (A'34) of Dorchester, Mass., is now at Philadelphia, Pa., with station WCAU.

Obituary

FRANKLIN WASHINGTON WOOD (A'05, M'20) marine electrical engineer, Great Neck, N. Y., died April 18, 1935. He was born at London, England, January 2, 1870. In 1887, 2 years after coming to America, he became associated with Chas. Cory and Son, Inc., manufacturers of marine signaling and intercommunicating equipment in New York, N. Y. During the period 1893 to 1907 Mr. Wood was engineer in charge of construction and installation work for them at Newport News, Va., after which he was appointed chief engineer with offices at New York. In 1914 he became vice president of the company, and in 1920 went to England as European representative, but because of ill health retired in 1926, although he maintained his interest in the industry. He returned to the United States in 1933, and accepted a position as consulting engineer for Chas. J. Henschel and Company, Inc., Amesbury, Mass. Mr. Wood is credited with holding over 100 patents, among which are engine direction and revolution indicator systems, d-c self-synchronizing motors, for many years standard in all U.S. Navy telegraphs for communication and fire control purposes, various types of electrical and mechanical signaling appara-

tus for submarines, and various marine lighting fixtures and wiring appliances. Numerous technical descriptions and treatises on the care and operation of these different equipments were prepared by him for the instruction of Navy and merchant marine personnel. Mr. Wood was a member of the Institute's marine (now applications to marine work) committee from 1913 to 1922.

Hassan Camil Ali Sabbah (M'29, F'33) electrical engineer, General Electric Company, Schenectady, N. Y., died March 31, 1935. He was born at Nabatiah, Beirut, Arabia, August 16, 1895, and studied at the American University of Beirut. During 1918 he commanded a military wireless station in Thrace, then taught mathematics at the Imperial College of Damascus, Syria, and the American University of Beirut. In 1921 he came to the United States, and for a short time studied at Massachusetts Institute of Technology. He entered the vacuum tube section of the engineering laboratory of the General Electric Company at Schenectady in 1923, where he was engaged in mathematical and experimental research, principally on rectifiers and inverters, receiving a number of United States and foreign patents covering his work. Mr. Sabbah was engaged in work on television and motors as well, and originated circuits for use with rectifiers. He prepared a series of articles on polyphase polycyclic static converters which were published in the *General Electric Review*, and his paper on the effect of circuits on arc backs in mercury arc rectifiers was read before the International Electric Congress at Paris in 1932.

Natalis Mazen (F'22) sous-directeur, Chemins de Fer de L'Etat Francais, La Roche, France, died in August 1934 according to word received at Institute headquarters. He was born at Clermont-Ferrand, France, May 2, 1863, and early became interested in railway work. As a pioneer of electric traction in France, during 1899–1900 he had charge of the installation and inauguration of the first electric traction on a large scale in France on a branch line between Paris and Versailles. For a time he was chief engineer of materials and operation and assistant director for the State railroads, and was for 18 years professor of a course of applied mechanics and of electric traction at the School Superior of Electricity at Paris. At the time of his election to the Institute he was honorary director of the railways of the State of France. Mr. Mazen also served as consulting engineer for railroads in southern France, railways in the province of Rhone and in Paris, and for a metallurgical company. He was a former president of the French Society of Electriciens, and a member and officer of a number of other societies.

Frank Bailey Steele (M'18) consulting engineer and deputy city engineer, Utica, N. Y., died April 17, 1935. He was born at Stewartson Furnace, Pa., May 25, 1885, graduating from Virginia Military Institute and entering the engineering apprentice course of the Westinghouse Electric and Manufacturing Company at East Pittsburgh, Pa., in 1905. Two years later, as assistant engineer in charge of construction for the company, he was engaged in work on government buildings in Washington, D. C., where he entered George Washington University, receiving the degree of electrical engineer in 1909. Later in that year he became electrical engineer for the Keystone Coal and Coke Company, Keystone, W. Va., and in 1913 accepted the position of power engineer with the Dayton Light and Power Company, Dayton, Ohio. Mr. Steele went to Utica in 1918 as vice president and general manager of the Utica Gas and Electric Company, resigning from this position in 1929. He then engaged in consulting engineering, and at the time of his death was on leave from his duties as deputy city engineer to serve as assistant to the Temporary Emergency Relief Administration commissioner.

Anthony Saunders Morris (A'04) Haverford, Pa., died recently. He was born April 13, 1862, and attended schools at Philadelphia, Pa., after which he entered Stevens Institute of Technology, from which he received the degree of mechanical engineer in 1884. He became connected with the Westinghouse Electric and Manufacturing Company in 1887 and remained there a number of years. Since 1915 he had been vice president of the Cresson-Morris Company, Philadelphia. Mr. Morris was about to be enrolled as a member for life of the Institute.

R. Seshasayee (A'31) consulting engineer, Messrs. Seshasayee Brothers, Ltd., Trichinopoly, India, died February 11, 1934, according to word just received at Institute headquarters. He first became an Associate in 1910. Mr. Seshasayee had been engaged in the construction of power plants of various sizes since 1913, installing diesel and small engine plants in a number of buildings and several towns.

Membership

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. If the applicant has applied for direct admission to a grade higher than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the national secretary before June 30, 1935, or Aug. 31, 1935, if the applicant resides outside of the United States or Canada.

Allen, E. W., Southwestern Bell Tel. Co., Dallas, Texas.
Alspaugh, R. M., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Bacon, E. Jr., Washington Water Pwr. Co., Spokane.
Becker, L. S., Harvard Graduate School of Business, Boston, Mass.
Belshe, R. L., Petroleum Rectifying Co. of Calif., Long Beach.
Bennett, R. D. (Fellow), Mass. Inst. of Tech., Cambridge.
Black, D. S., Ohio Brass Co., Mansfield, Ohio.
Blascak, S. J. (Member), American Tel. & Tel. Co., New York City.
Braun, E. C., General Meter Service Corp., Brooklyn, N. Y.
Brown, R. D., Jr., Philadelphia Storage Battery Co., Philadelphia, Pa.
Carney, E. M., Brooklyn Edison Co., Brooklyn, N. Y.
Carral, C. S., General Elec. S. A., Mexico D. F., Mexico.
Cisler, W. L. (Member), Public Service Elec. & Gas Co., Newark, N. J.
Daykin, H. R., Bostwick-Braun Co., Toledo, Ohio.
DeKinder, J. M., Bureau of Reclamation, Lovelock, Nev.
Dogan, A. E., University of New Hampshire, Durham.
Doolittle, H. S. (Member), Six Companies, Boulder City, Nev.
Farmer, A. C., Westinghouse Elec. & Mfg. Co., Sharon, Pa.
Frisby, E. F., Virginia Elec. & Pwr. Co., Richmond, Va.
Fung, J. T. S., 2100 Monterey Blvd., San Francisco, Calif.
Gentsch, E. J., Picker X-Ray Co., New York City.
Gore, C. W., Clark & Wilson Lumber Co., Linnton, Ore.
Hafely, C. H., Ford Instrument Co., Inc., Long Island City, N. Y.
Hewett, J. L., Jensen Bowen & Farrell, Ann Arbor, Mich.
Irwin, E. M. (Member), Calif. Inst. of Tech., Pasadena.
Lazo, R. L., N. Y. State Public Service Comm., New York.
Lee, M., Burndy Engg. Co., Inc., New York, N. Y.
Linklater, T. B., Ontario Forestry Branch Radio, Toronto, Can.
Loewel, M. E., Western Elec. Co., Inc., New York City.
McDunnough, P. N., Shawinigan Water & Pwr. Co. Montreal, Que., Can.
McEntee, A. L., Consolidated Elec. Lamp Co., Lynn, Mass.
Morgan, C. F., Oklahoma Gas & Elec. Co., Drumright.
Mouat, T. W. Jr., Canadian Elec. Mfg. Co., Ltd, Vancouver, Can.
Pendleton, O. A. (Member), The Empire Dist. Elec. Co., Joplin, Mo.
Peterson, H. A., General Elec. Co., Pittsfield, Mass.
Schwartz, A., 161 Jackson Ave., Jersey City, N. J.
Tolman, S. C., 32 High St., New Haven, Conn.
Walmsley, C. A., N. Y. & Queens Elec. Lt. & Pwr. Co., Long Island City, N. Y.
Watson, L. A. (Member), Clark Contracting Co., Cleveland, Ohio.
Whitney, H. V., General Elec. Co., Richmond, Va.
Wikstrom, A. (Member), Cornell Univ., Ithaca, N. Y.
Young, D. A., Westinghouse Elec. & Mfg. Co., Newark, N. J.

42 Domestic

Foreign

Harvey, A. Q. (Member), Springs Municipality, Transvaal, South Africa.
Iyer, S. N., Hubli Elec. Co. Ltd., Hubli, Dharwar Dist., Bombay, India.
Mathews, J. T., Westinghouse Elec. & Mfg. Co., Berlin, Siemensstadt, Germany.
Thorburn, R. W., Allmanna Svenska Elektriska Aktiebolaget, Herrgarden, Ludvika, Sweden.
Trivedi, T. N., The Katni Cement & Industrial Co. Ltd., Katni, India.

5 Foreign

Addresses Wanted

A list of members whose mail has been returned by the postal authorities is given below, with the address as it now appears on the Institute record. Any member knowing of corrections to these addresses will kindly communicate them at once to the office of the secretary at 33 West 39th St., New York, N. Y.

French, Benedict, V. K., c/o United American Bosch Corp., Springfield, Mass.
Germenshausen, K. J., M.I.T. Dorm., Cambridge, Mass.
Golikoff, A., Main P. O. Gen. Del., Moscow, U.S.S.R.
Greene, F. M., 656—50th St., Brooklyn, N. Y.
Haddad, Raphael A., 500 Riverside Drive, N. Y. City.
Hansen, A. Fred, 2065½ W. 30th St., Los Angeles, Calif.
Houston, Chas. E., 400—10th Ave., S. E., Minneapolis, Minn.
Rasmussen, David, 423 Hickory St., Ridgway, Pa.
Rozelle, P. M., 2018 Chestnut St., Harrisburg, Pa.
Smedley, A. B., 82 Warner Ave., Hempstead, N. Y.
Thomson, W. L., 3630 Spruce St., Philadelphia, Pa.
Verrier, E. J., Anglo Newfoundland Dev. Co., Grand Falls, Newfoundland.
Watson, J. Connell, 69 Cambridge Terrace, London, W. 2, Eng.

13 Addresses Wanted

Engineering Literature

New Books in the Societies Library

Among the new books received at the Engineering Societies Library, New York, recently, are the following which have been selected because of their possible interest to the electrical engineer. Unless otherwise specified, books listed have been presented gratis by the publishers. The Institute assumes no responsibility for statements made in the following outlines, information for which is taken from the preface of the book in question.

SCHWEIZ. VERBAND für die MATERIALPRÜFUNGEN der TECHNIK (Association Suisse pour l'Essai des Materiaux). Diskussionsbericht No. 27, Bericht No. 69 der Eidg. Materialprüfungsanstalt. Zürich, Jan. 1933. 57 p., illus., 12x8 in., paper, apply. These papers, read before sections of the Swiss Society for Testing Materials, discuss the determination of the tensile strength of paper, pasteboard, and cloth used for electrical insulation, the determination of humidity, the testing of cotton, and the testing of the permanency of colors.

SCIENCE MUSEUM (South Kensington). HANDBOOK of the COLLECTIONS illustrating ELECTRICAL ENGINEERING. RADIO COMMUNICATION, Pt. 1, History and Development. By W. T. O'Dea. London, His Majesty's Stationery Office, 1934. 95 p., illus., 10x6 in., paper, 2s 6d. Starting with the history of our knowledge of electromagnetic waves and of detectors, this work proceeds to describe early experiments in wireless telegraphy and the development to commercial practice. The history of thermionic valve and of the development of methods of speech transmission and television is given.

SERVICE CHARACTERISTICS of the LIGHT METALS and THEIR ALLOYS, prepared by Subcommittee VII of Committee B-7 on Light Metals and Alloys, Cast and Wrought. Phila., American Society for Testing Materials, 1934. Vol. 34, Pt. 1, 33 p., tables, 9x6 in., paper, $.50. This pamphlet is intended to present the essential data about aluminum and magnesium and their more important alloys in a concise form. The metallurgical characteristics of the metals are discussed, their usefulness in certain industrial fields is explained, surface protection by painting, anodizing, or electroplating is described, and tables are given of the trade designations, compositions, physical constants, mechanical properties and foundry characteristics of various alloys.

SIGNIFICANCE of TESTS of PETROLEUM PRODUCTS, a Report Prepared by A.S.T.M. Committee D-2 on Petroleum Products and Lubricants. Phila., Pa., American Society for Testing Materials, 1934. 76 p., illus., 9x6 in., paper, $1.00. This report is intended to give the general public authoritative information about the applicability of the tests in common use for petroleum products and lubricants, and the significance of the results. It aims to assist in the proper choice of tests and their correct interpretation.

APPLICATIONS de l'ÉLECTRICTITÉ. (Memento d'Électrotechnique—IV). By A. Curchod. Paris, Dunod, 1935. 831 p., illus., 9x5 in., paper, 136 frs.; bound, 146 frs. The final volume of a reference work covering the whole field of electrical engineering, and discussing the applications of electricity.

Care and Repair of FRACTIONAL-HORSE-POWER MOTORS. By A. G. Smith. Scranton, Pa., International Textbook Co., 1933. 126 p., illus., 8x5 in., lea., $1.10. A manual of practical information for the electrician, describing each main type and design, and windings.

GASENTLADUNGSTABELLEN, Tabellen, Formeln und Kurven zur Physik und Technik der Elektronen und Ionen. By M. Knoll, F. Ollendorff and R. Rompe. Berlin, Julius Springer, 1935. 171 p., illus., 10x7 in., cloth, 29 rm. Formulas, tables, and charts upon the physical behavior of atoms, electrons, and photons; the kinetic theory of gases; the kinetics of charge carriers and their ionization phenomena; the properties of vacuum tubes; high vacuum technique, etc.

Great Britain. Dept. of Scientific and Industrial Research. Report of the FOREST PRODUCTS RESEARCH BOARD, 1933. Lond., His Majesty's Stationery Office; (obtainable from British Library of Information, N. Y.) 1934. 67 p., illus., 10x6 in., paper, ls 3d.; $.45. A summary of investigations of methods of seasoning timber, timber preservatives, the chemistry of decay, insect damage, etc.

LIGHTING CALCULATIONS. By H. H. Higbie. N. Y., John Wiley & Sons, 1934. 503 p., illus., 9x6 in., cloth, $5.00. The problem method of teaching applied to illumination engineering, together with the lighting data needed by the student

NEON, a Handbook for Electrical Engineers. Neon Manufacturers, Sign Salesmen and Advertisers. By S. Gold. Lond., Crosby Lockwood & Son, 1934. 178 p., illus., 9x6 in., cloth, 7s 6d. The design, manufacture, and installation of neon signs in non-technical terms.

Les RÉSEAUX de TRANSMISSION d'ÉNERGIE, Réglage et Stabilité, Surintensités, Surtensions, Protection Sélective. By J. Fallou. Paris, Gauthier-Villars, 1935. 558 p., illus., 10x7 in., paper, 125 frs. A discussion of the chief problems encountered in the construction and operation of transmission systems, covering theory, regulation, overloads, and protection.

MACHINE DESIGN, 3 vols. By M. E. Steczynski. Scranton, Pa., International Textbook Co., 1933, illus., 8x5 in., lea., vol. 1, 130 p., $1.25; vol. 2, 154 p., $1.50; vol. 3, 160 p., $1.75. An elementary course in practical machine design, intended primarily for home study; only elementary mathematics is used, and theoretical discussions omitted.

Science Museum, Lond. Board of Education. Technical Pamphlet No. 2. The AUTOMATIC TELEPHONE, by W. T. O'Dea. London, His Majesty's Stationery Office; (obtainable from British Library of Information, N. Y.) 1934. 13 p., illus., 10x6 in., 6d.; $.20. Non-technical description of the Strowger automatic telephone systems.

SCIENCE of WORK. By M. S. Viteles. N. Y., W. W. Norton & Co., 1934. 442 p., diagrs., 9x6 in., cloth, $4.00. A non-technical discussion of the applications of psychology to industry. Personnel selection, methods of training, the effect of various influences upon output, etc., are considered.

V D E—FACHBERICHTE 1934. Berlin-Charlottenburg 4, Verband Deutscher Elektrotechniker, 1934. 152 p., illus., 12x8 in., paper, 10.20 rm; bound, 13.50 rm. The technical proceedings of the Stuttgart, 1934, meeting of the Verband deutscher Elektrotechniker, containing 44 papers.

AMERICAN SOCIETY for TESTING MATERIALS, PROCEEDINGS of the 37th Annual Meeting, v. 34, 2 v., 1934. Phila., American Society for Testing Materials, illus., 9x6 in., cloth, v. 1, 1325 p.; v 2, 943 p., cloth, $6.00; half leather, $7.00 each. Part 1 contains the reports of committees, the "tentative standards," and the tentative revisions of standard specifications and tests. Part 2 includes the papers and discussions upon metals, cements, ceramics, masonry, paints, rubber, and other topics.

The CHALLENGE to LIBERTY. By H. Hoover, N. Y. and Lond., Charles Scribner's Sons, 1934. 212 p., 8x6 in., cloth, $1.75. A discussion of the pressing political and economic questions of the day, and criticism of current tendencies in the treatment of national problems.

DIESEL HAND BOOK, a Practical Book of Instruction for Engineers and Students on Modern Diesel Engineering, Land, Marine, Locomotive, Aero, Automotive and Portable Installations. 2nd ed. By J. Rosbloom. Jersey City, Diesel Engineering Institute, 1935. 543 p., illus., 7x5 in., lea., $5.00. A practical text and reference book for the operating engineer, presented largely in questions and answers.

MacRae's BLUE BOOK consolidated with Hendricks' Commercial Register. 42nd annual edition. Chicago, MacRae's Blue Book Co., 1934. 3340 p., illus., 11x8 in., cloth, $15.00. A directory of manufacturers and distributors of materials of all kinds, a classified list of materials, a directory of towns and cities, with their facilities for trade, and a list of trade names.

MISSISSIPPI VALLEY COMMITTEE of the PUBLIC WORKS ADMINISTRATION. Report Submitted October 1, 1934 to Harold L. Ickes, Administrator of Federal Emergency Administration of Public Works. U.S. Government Printing Office, Washington, D. C., 1934. 234 p., illus., 12 x 9 in., cloth, $1.50. The complete text of the report upon the use and control of water within the Mississippi drainage basin.

ELECTRONS (+ and −), PROTONS, PHOTONS, NEUTRONS, and COSMIC RAYS. By R. A. Millikan. Chicago, Univ. of Chicago Press, 1935. 492 p., illus., 8x5 in., cloth, $3.50. A nonmathematical review of recent discoveries and developments in physics, replacing the author's former book, "The Electron."

HIGH VOLTAGE PHYSICS. By L. Jacob. Lond. Methuen & Co., 1934. 107 p., illus., 7 x 4 in., cloth, 3s. A survey in outline of the physics of high voltage phenomena.

PRINCIPLES of ALTERNATING CURRENTS. By R. R. Lawrence. 2 ed. N. Y. and Lond., McGraw-Hill Book Co., 1935. 475 p., illus., 8x6 in., cloth, $4.00. A text for college students and a presentation of alternating current theory for reference use in practice.

X-RAYS in THEORY and EXPERIMENT By A. A. Compton and S. K. Allison. N. Y., D. Van Nostrand Co., 1935. 828 p., illus., 9x6 in., cloth, $7.50. A comprehensive view of the whole field of X-rays, and discussion of the theory of the phenomena.

ATOMIC STRUCTURE and SPECTRAL LINES. I, By A. Sommerfeld, translated from the 5th German ed. by H. L. Brose. N. Y., E. P. Dutton & Co., 1934, 675 p., illus., 9x6 in., cloth, $10.80. The new edition will appear in 2 volumes, the present one containing the older quantum theory.

AUTOMATIC PROTECTION of A-C CIRCUITS. By G. W. Stubbings. Pittsburgh, Instruments Pub. Co, 1935. 293 p., illus., 9x6 in., cloth, $5.00. A discussion of the theory of protective transformers and their interconnection, the theory of protective relays, the protection of electrical machinery and cable networks, and the testing and maintenance of protective gear.

DESIGN of A-C MACHINES, TRANSFORMERS. By C. D. Sasscer and D. D. Coffin. $2.40. DESIGN of DIRECT CURRENT MACHINES. By S. Hancock. $2.15. Scranton, Pa., International Textbook Co., 1934. Ills., 8x5 in., lea. A practical course in the design of electrical machines, using only simple mathematics and a minimum of theoretical discussion.

Deutsches Museum. Abhandlungen und Berichte, Jg. 6, Heft 3. NEUZEITLICHE LICHTERZEUGUNG MITTELS GASENTLADUNGSLAMPEN. By E. Lax. Berlin, VDI-Verlag, 1934. 81 p., illus., 8x6 in., paper, 90 rm. A popular account of modern methods of illumination, covering light, gaseous discharges, and modern gas filled lamps.

ELEKTROINSTALLATION in der SIEDLUNG, Vorbilder und Richtlinien. By M. Mengeringhausen, ed. by F. Hoppe. Berlin, VDI-Verlag, 1935. 11 p., diagrs., 12x8 in., paper, 1.90 rm. A pamphlet giving plans and standards for economical distribution in small villages.

ELEMENTARY MECHANICS. By J. B. Reynolds. rev. ed. N. Y., Prentice-Hall, 1934. 336 p., diagrs., 9x6 in., cloth, $2.75. A text for a first course in mechanics in technical schools, calling for only an elementary knowledge of algebra and geometry, and confined to the easier applications.

ELEMENTS of LOUD SPEAKER PRACTICE. By N. W. McLachlan. Lond. and N. Y., Oxford Univ. Press, 1935. 160 p., illus., 8x5 in., cloth, $1.75. Nontechnical explanation of the purpose, working, design, and effect of placement of loud speakers.

Engineering Societies Library

29 West 39th Street, New York, N. Y.

MAINTAINED as a public reference library of engineering and the allied sciences, this library is a cooperative activity of the national societies of civil, electrical, mechanical, and mining engineers.

Resources of the library are available also to those unable to visit it in person. Lists of references, copies or translation of articles, and similar assistance may be obtained upon written application, subject only to charges sufficient to cover the cost of the work required.

A collection of modern technical books is available to any member residing in North America at a rental rate of five cents per day per volume, plus transportation charges.

Many other services are obtainable and an inquiry to the director of the library will bring information concerning them.

Industrial Notes

Large Steel Mill Order to Westinghouse.—Contracts have been awarded to the Westinghouse Electric & Mfg. Co., amounting to approximately $1,250,000 by the Bethlehem Steel Co. for motors, control and power equipment to be installed in new hot and cold strip mills of the Lackawanna Plant of the steel company, at Buffalo. The electrical units include: four 3000-hp and one 1000-hp alternating-current motors, nine 1250-hp direct-current motors, and one 2500-kilowatt and one 1300-kilowatt motor-generator sets. Westinghouse is also supplying nearly 800 motors and variable frequency units for the roll tables of the mills and motors, motor-generator sets and control for a flying shear which catches and cuts to accurate lengths strip steel as it passes through the final rolling process. Westinghouse equipment will be installed to provide a cool air circulating system to ventilate the larger motors and motor-generator sets. Nearly all of the apparatus will be made in East Pittsburgh, work to start immediately.

Sherwin-Williams Appointment.—Announcement is made by The Sherwin-Williams Co., Cleveland, that H. J. L. Cotton has been appointed head of the insulating varnish and compound division of that company. Mr. Cotton was formerly assistant to Dr. Ware in the Varnish Research Department of the company.

New Brass-Bushed Insulators.—The Hemingray Division of the Owens-Illinois Glass Co., Muncie, Ind., has introduced a new line of brass-bushed glass insulators. The bushing is locked into position without cement or alloy to hold it in place, assuring smooth, perfect pin threads, eliminating breakage due to pin expansion and causing no radio interference. The most important advantage, however, is the greatly increased mechanical strength. Higher dielectric properties are also characteristic of the new insulator. All styles of the new insulators are made in clear and brown color glass with ratings up to 15,000 volts.

New Farm-Line Transformer.—The Wagner Electric Corporation of St. Louis has developed a new line of farm-line distribution transformers designed to reduce installation and maintenance costs and to provide maximum protection against lightning. They are manufactured in 1- and 3-kva sizes, 60 cycles, 2400 to 7620 voltage classes, for operation on a three-phase, four-wire service with solidly-grounded neutral. Standard 1-kva ratings are provided with two low-voltage leads for single-wire, low-voltage service (i. e., 120 volts). Standard 3-kva ratings are provided with three low-voltage leads for three-wire, low-voltage service (i. e., 120/240-volts).

New Graphic Kilovolt-Ampere Meter.—The Esterline-Angus Co., Indianapolis, Ind., announces a new kilovolt-ampere recording instrument, designed for use in making a continuous record of electrical energy. The new instrument embodies the standard model A.W. wattmeter in conjunction with a phase shifting net work which supplies the wattmeter with a lagging potential corresponding to the average power factor of the circuit. By means of three sets of taps, the instrument is made to cover a range of power factor from .54 to .94, with an error not to exceed $1^1/_2$ per cent. A tap is provided on the phasing net work, to permit measurement of reactive volt-amperes with the same instrument. By omitting the network, the instrument can be used as a graphic wattmeter. The instrument is furnished either as a complete unit including graphic wattmeter and phasing network, or the network can be furnished separately for use with existing meters. It is supplied in a combination 100–200 volt range, potential transformers being employed for higher voltages. These instruments are made in flush, front of board, wall, and portable types.

Improved Paper-Insulated Cable.—Five major improvements in the construction of paper-insulated cable which result in cable of smaller diameter over-all, higher dielectric strength, increased reliability, and longer life have been announced by the General Electric Co. The first of these improvements is a new compact-strand conductor which reduces the diameter of the cable, gives it higher dielectric strength, lowers the a-c resistance, and results in longer life. In addition, the change from annular to segmented construction in large single-conductor cable increases the current-carrying capacity for a given diameter. Second, the layers of insulation are graduated, with super-dense paper next to the conductor, improving the mechanical and dielectric strength. Third, the insulation is washed in carbon-dioxide gas, providing a more thorough impregnation and eliminating oxygen and moisture. Fourth, the lead sheath is applied by the General Electric hydrogen process which eliminates oxidized areas and provides a sheath free from weak and inferior spots. Fifth, on all classes of G-E Type H cable, the metal shields are interlocked with paper tapes, which results in more satisfactory shielding.

Trade Literature

Direct Current Generators.—Bulletin 1171, 12 pp. Describes generators for industrial, railway and power station service. Allis-Chalmers Mfg. Co., Milwaukee, Wis.

Circuit Breakers.—Bulletin GEA-1972, 4 pp. Describes type FK-144A, high-speed, oil-tight, circuit breakers for 50,000-kva service; 600 amperes, 15,000 volts; 1200 amperes, 7500 volts. General Electric Co., Schenectady, N. Y.

Air-Conditioning System Regulation.—Bulletin 4001, 24 pp. Describes and illustrates the application of electrical thermometers in and the efficient regulation of air-conditioning systems. Leeds & Northrup Co., 4901 Stenton Ave., Philadelphia.

Potentiometers.—Bulletin 270, 8 pp. Describes potentiometers for laboratory and industrial use, including slide wire, simplified laboratory, precision laboratory, portable precision and high precision instruments. Rubicon Co., 29 No. Sixth St., Philadelphia.

Mercury Arc Power Rectifiers.—Bulletin 1169, 12 pp. Describes mercury arc power rectifiers (Brown Boveri design) for converting alternating to direct current. Installations are pictured. Allis-Chalmers Mfg. Co., Milwaukee, Wis.

Portable Electric Tools.—Silver Anniversary Catalog, 50 pp. Includes a comprepensive description, with prices, of a wide variety of portable tools, including drills, saws, hammers, grinders, sanders and polishers, bench grinders, valve refacers, etc. Black & Decker Mfg. Co., Towson, Md.

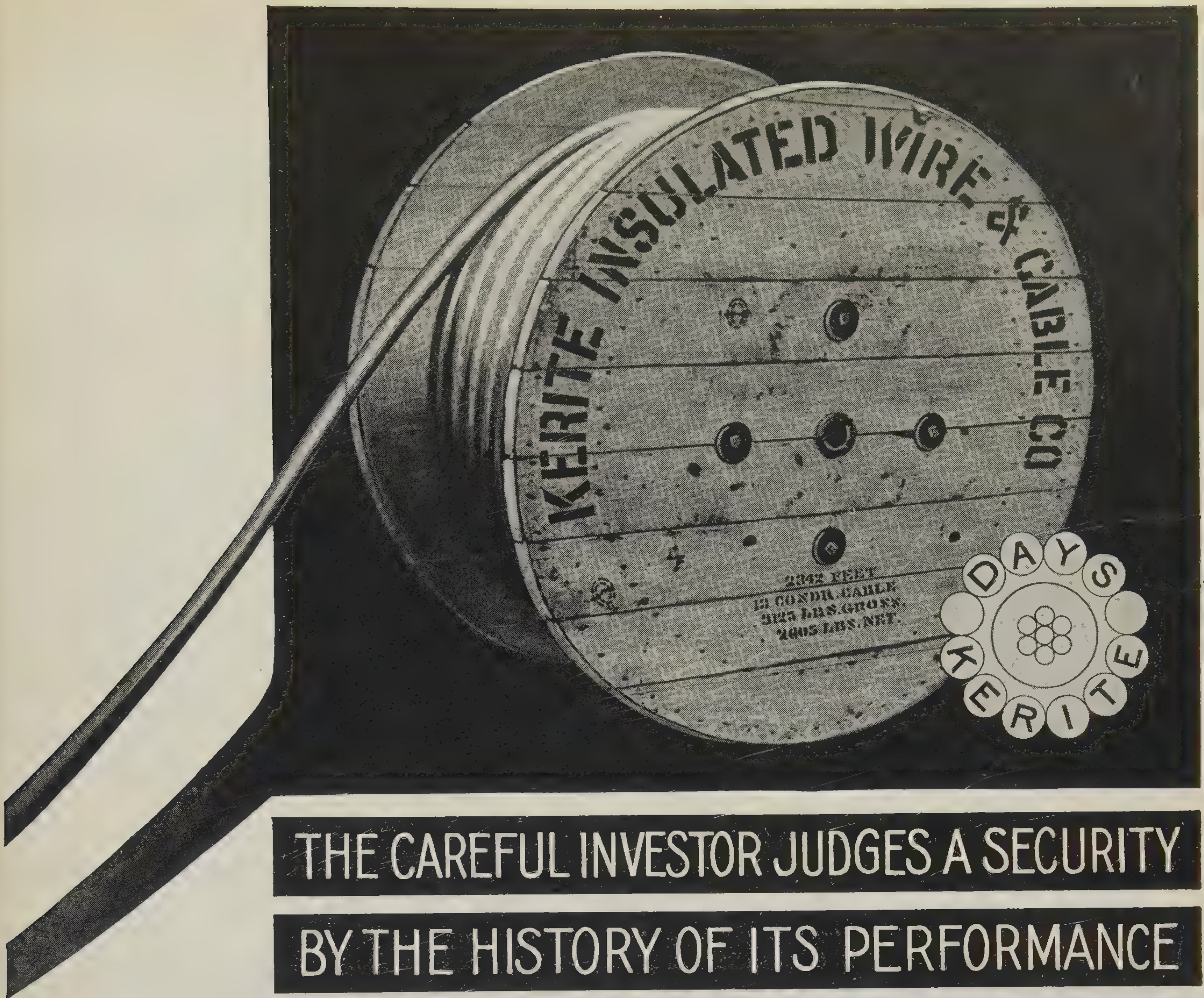
Polyphase Motors.—Bulletin, 8 pp. Describes Century squirrel-cage, induction polyphase motors, $^1/_6$ to 600 hp; open, enclosed, explosion proof, totally-enclosed fan-cooled, gear splash-proof, multispeed, general purpose and special characteristics. Century Electric Co., 1806 Pine St., St. Louis, Mo.

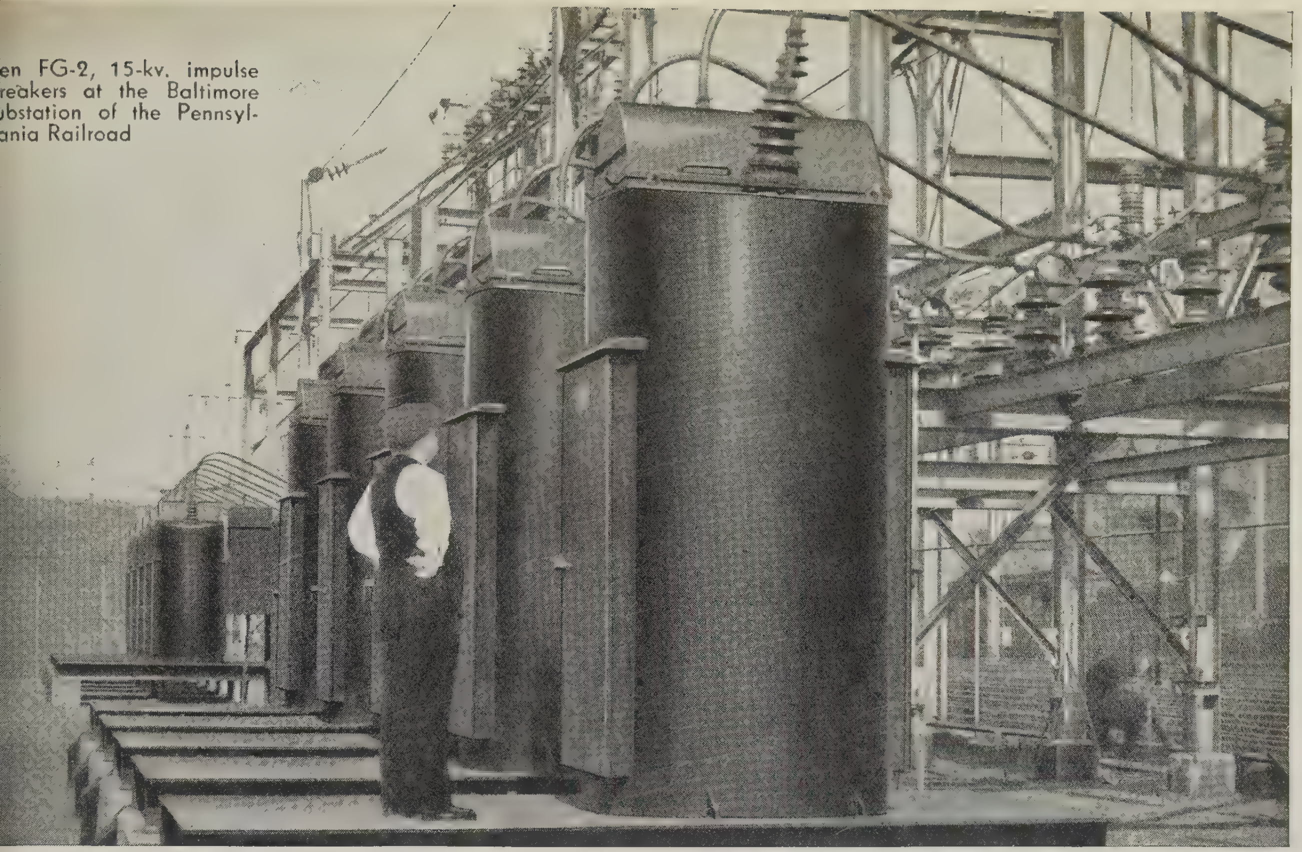
Electric Heating Systems.—Bulletin, 12 pp. Describes the Hynes electric heating systems, with automatic control, for rooms, buildings, power plants, hydro stations, substations, dam gates, water tanks, etc. Typical installations together with names of many industrial and public utility users are included. Hynes Electric Heating Co., 240 Cherry St., Philadelphia.

Instruments.—Catalog 48. Describes a-c and d-c, panel and switchboard type, $3^1/_2$, 4, $7^1/_2$ and 9 inch round pattern and rectangular, horizontal edgewise and illuminated dial ammeters, milliammeters, voltmeters, milli-voltmeters, pyrometers, single and polyphase wattmeters, frequency and power factor meters and accessories. Roller-Smith Co., 233 Broadway, New York.

Welding Electrodes.—Bulletin 2, 16 pp. Describes Murex all-mineral coated welding electrodes. Considerable technical data, covering principles of design and operation, as well as physical properties and chemical analysis of deposited metals, are included. Illustrated, showing applications of various types of electrodes. Metal & Thermit Corp., 120 Broadway, New York.

Electrical Application of Plastics.—Bulletin 4 pp. Discusses insulation characteristics and describes a service to electrical manufacturers for the selection and proper design of insulating materials for use in electrical apparatus. This company assists in the design of apparatus and devices for any operating potential up to 220,000 volts and test potentials of 2 million volts. Examples of work accomplished are illustrated. Another bulletin on moisture proofing, from an insulating standpoint, is also available. Joseph C. Rah & Co., 5745 West Ohio St., Chicago.


KERITE INSULATED WIRE & CABLE CO
2342 FEET
13 CONDR. CABLE
3125 LBS. GROSS
2605 LBS. NET
DAYS
KERITE



en FG-2, 15-kv. impulse reakers at the Baltimore ubstation of the Pennsylvania Railroad

What these smashed records mean

Impulse breakers will interrupt the circuit in about one-third the time required by conventional-type breakers, will improve system stability and continuity of service, and prevent damage to generators, transformers, and cable due to short circuits. Telephone interference on parallel communication circuits will also be reduced.

The low oil content eliminates the need of special oil-handling equipment, makes quick inspection easy, and reduces oil-replacement cost. The total weight of the breaker is decreased, which simplifies installation.

The advantages of oil-blast — Plus

Oil driven between the opening contacts interrupts the arc. Pistons actuated by the operating mechanism supply the oil pressure, instead of the arc itself as in oil-blast breakers. Thus the "impulse" method provides extremely rapid interruption.

For railway electrification

Impulse breakers, rated 15,000 volts, have an enviable record on the Reading Railway. Many are in service on the Pennsylvania's electrified line between New York and Washington. They protect 25-cycle, 11,000-volt trolley circuits, interrupting in 1 cycle or less. Tests during the last three years show them to be equally successful for high-voltage service.

For transmission lines

Twelve impulse breakers are being built for the Bureau of Power and Light of the City of Los Angeles for the control and protection of the Boulder Dam–Los Angeles transmission lines. Eight will operate at 287.5 kv.—higher than any operating voltage now in use. Four will operate at 138 kv. Both have a rated operating time of three cycles (60-cycle basis) as compared with eight cycles, the fastest heretofore for high-voltage breakers of the usual type.

A complete description of the breakers for Boulder Dam is available in a reprint, No. GEA-2121, of an A.I.E.E. paper by D. C. Prince. For copies, address the nearest G-E office, or General Electric, Dept. 6E -201, Schenectady, N. Y.

810-51

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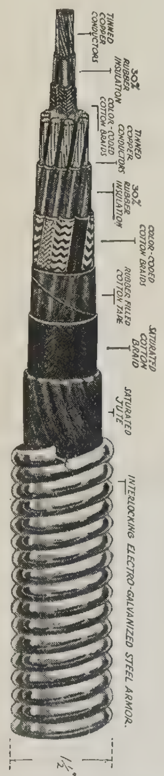

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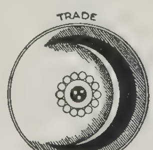

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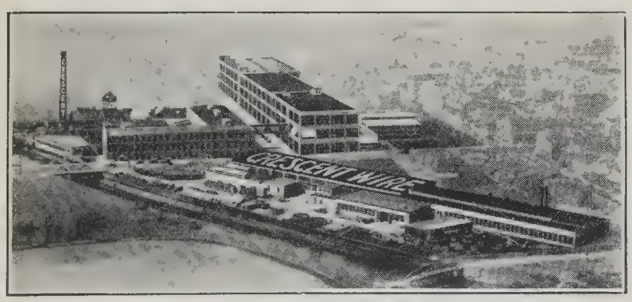

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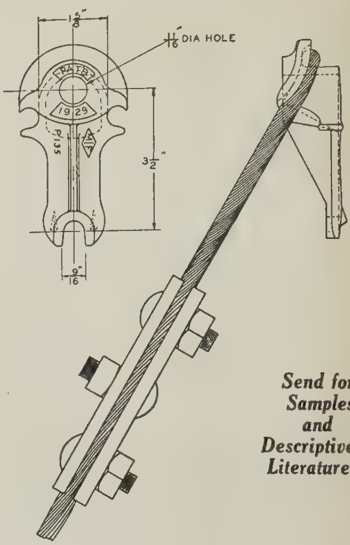

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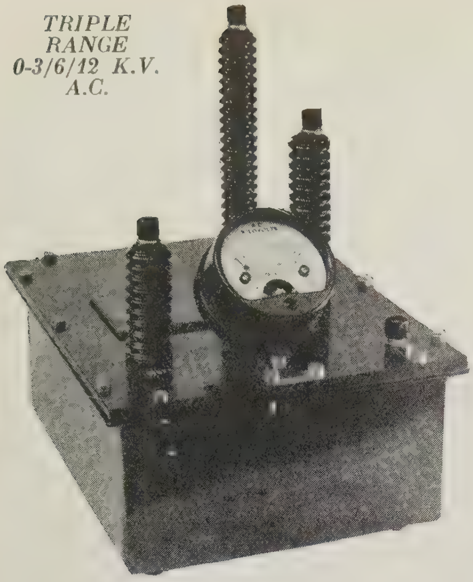

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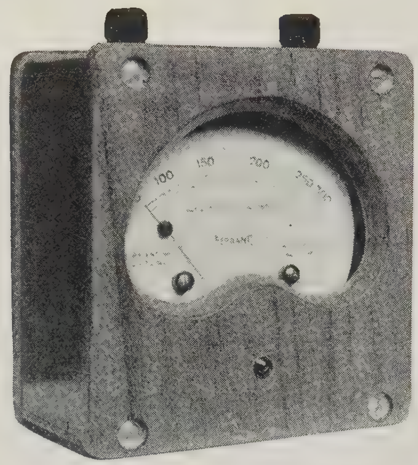

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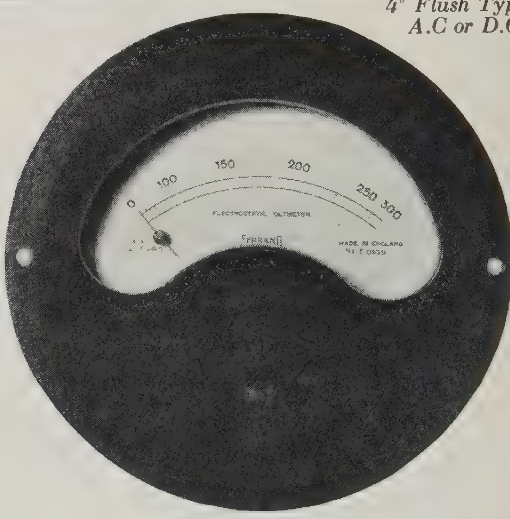

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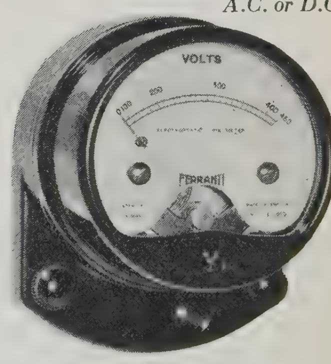

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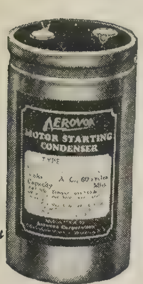

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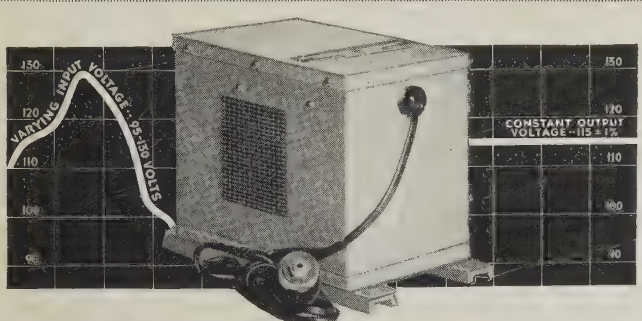

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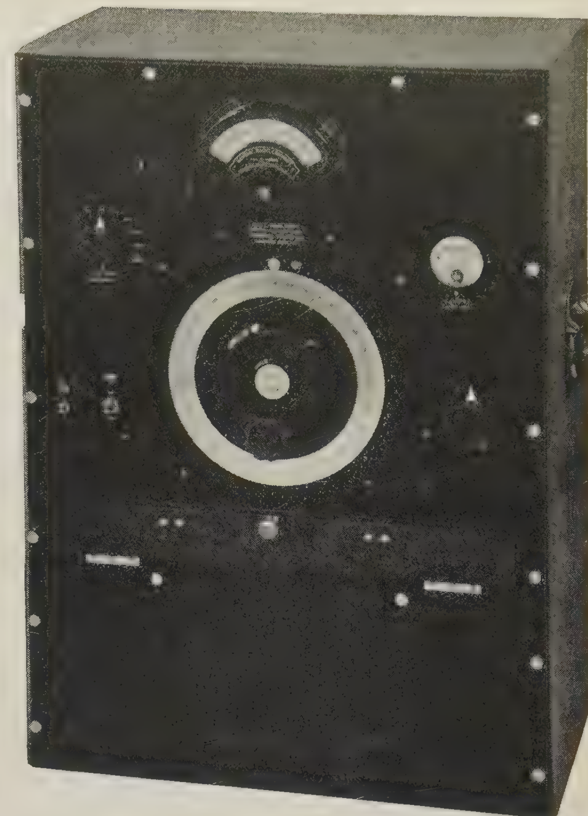

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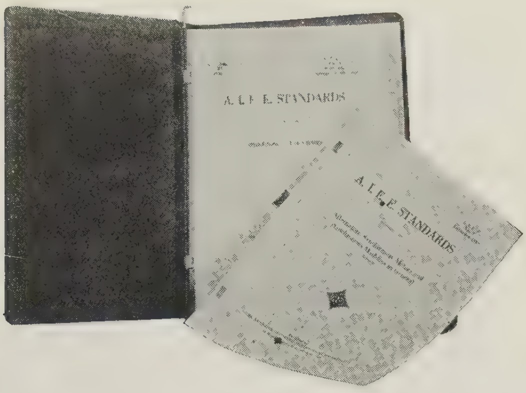

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General Electric Co., Schenectady, N. Y.

WELDERS, ARC
General Electric Co., Schenectady, N. Y.

WELDING WIRE
American Steel & Wire Co., Chicago
General Electric Co., Schenectady, N. Y.
Roebling's Sons Co., John A., Trenton, N. J.

WIRES AND CABLES
Armored Cable
American Steel & Wire Co., Chicago
Crescent Ins. Wire & Cable Co., Trenton, N. J.
General Cable Corp., New York
General Electric Co., Schenectady, N. Y.
Kerite Ins. Wire & Cable Co., New York
Okonite Company, The, Passaic, N. J.
Roebling's Sons Co., John A., Trenton, N. J.
Asbestos Covered
American Steel & Wire Co., Chicago
General Electric Co., Schenectady, N. Y.
Okonite Company, The, Passaic, N. J.
Roebling's Sons Co., John A., Trenton, N. J.
Automotive
American Steel & Wire Co., Chicago
Crescent Ins. Wire & Cable Co., Trenton, N. J.
General Cable Corp., New York
General Electric Co., Schenectady, N. Y.
Kerite Ins. Wire & Cable Co., New York
Okonite Company, The, Passaic, N. J.
Roebling's Sons Co., John A., Trenton, N. J.
Bare Copper
American Steel & Wire Co., Chicago
Copperweld Steel Co., Glassport, Pa.
Crescent Ins. Wire & Cable Co., Trenton, N. J.
General Cable Corp., New York
Roebling's Sons Co., John A., Trenton, N. J.
Bronze
Copperweld Steel Co., Glassport, Pa.
Copper Clad
American Steel & Wire Co., Chicago
Copperweld Steel Co., Glassport, Pa.
General Cable Corp., New York
Copperweld
Copperweld Steel Co., Glassport, Pa.
Flexible Cord
American Steel & Wire Co., Chicago
Crescent Ins. Wire & Cable Co., Trenton, N. J.
General Cable Corp., New York
General Electric Co., Schenectady, N. Y.
Okonite Company, The, Passaic, N. J.
Roebling's Sons Co., John A., Trenton, N. J.
Fuse
American Steel & Wire Co., Chicago
General Electric Co., Schenectady, N. Y.
Roebling's Sons Co., John A., Trenton, N. J.
Heavy Duty Cord
American Steel & Wire Co., Chicago
Crescent Ins. Wire & Cable Co., Trenton, N. J.
General Cable Corp., New York
Okonite Company, The, Passaic, N. J.
Roebling's Sons Co., John A., Trenton, N. J.
Lead Covered (Paper and Varnished Cambric Insulated)
American Steel & Wire Co., Chicago
Crescent Ins. Wire & Cable Co., Trenton, N. J.
General Cable Corp., New York
General Electric Co., Schenectady, N. Y.
Kerite Ins. Wire & Cable Co., New York
Okonite Company, The, Passaic, N. J.
Okonite-Callender Cable Co., Passaic, N. J.
Roebling's Sons Co., John A., Trenton, N. J.
Magnet
American Steel & Wire Co., Chicago
Crescent Ins. Wire & Cable Co., Trenton, N. J.
General Cable Corp., New York
General Electric Co., Schenectady, N. Y.
Roebling's Sons Co., John A., Trenton, N. J.
Rubber Insulated
American Steel & Wire Co., Chicago
Crescent Ins. Wire & Cable Co., Trenton, N. J.
General Cable Corp., New York
General Electric Co., Schenectady, N. Y.
Kerite Ins. Wire & Cable Co., New York
Okonite Company, The, Passaic, N. J.
Roebling's Sons Co., John A., Trenton, N. J.
Tree Wire
American Steel & Wire Co., Chicago
Crescent Ins. Wire & Cable Co., Trenton, N. J.
General Cable Corp., New York
Kerite Ins. Wire & Cable Co., New York
Okonite Company, The, Passaic, N. J.
Roebling's Sons Co., John A., Trenton, N. J.
Trolley
American Steel & Wire Co., Chicago
General Cable Corp., New York
Copperweld Steel Co., Glassport, Pa.
Roebling's Sons Co., John A., Trenton, N. J.
Weatherproof
American Steel & Wire Co., Chicago
Crescent Ins. Wire & Cable Co., Trenton, N. J.
General Cable Corp., New York
Copperweld Steel Co., Glassport, Pa.
General Electric Co., Schenectady, N. Y.
Okonite Company, The, Passaic, N. J.
Roebling's Sons Co., John A., Trenton, N. J.

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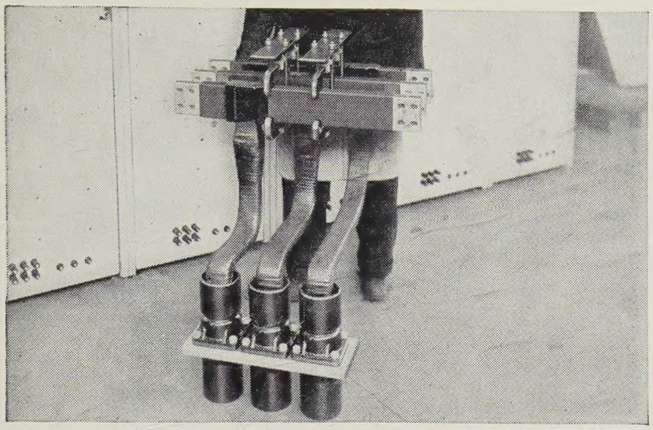
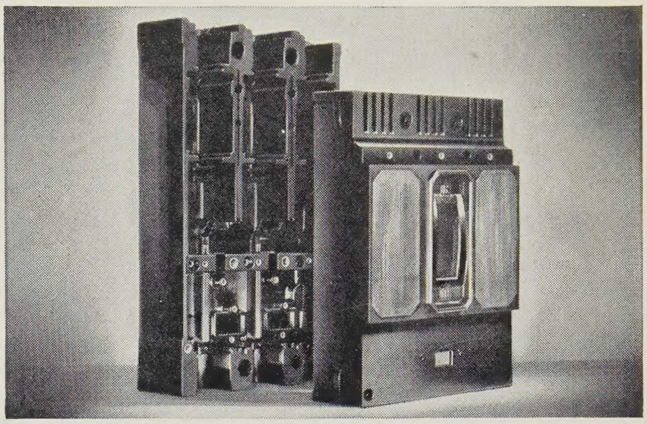
Four Examples of Modernization

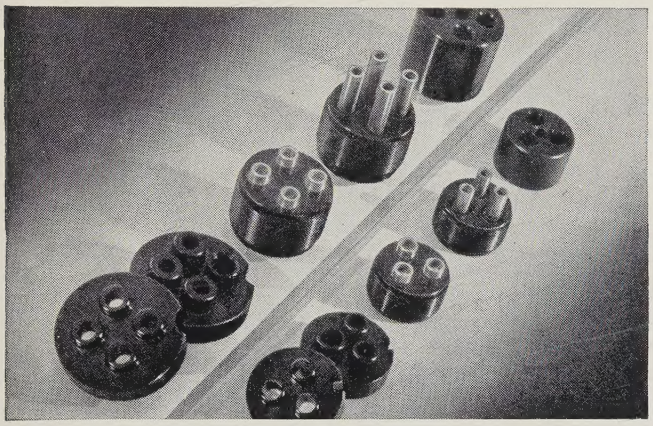
with Bakelite Materials



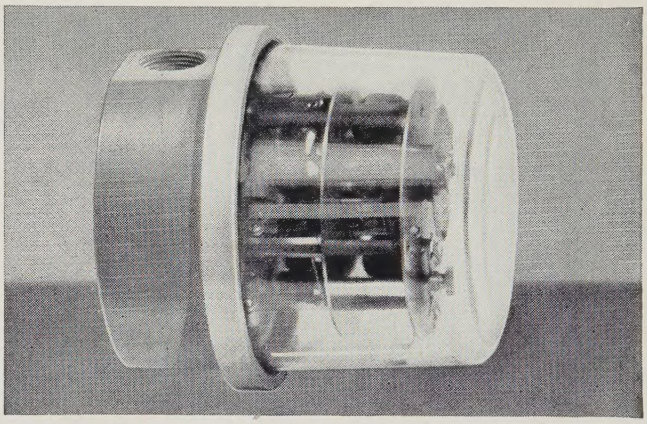
SWITCHGEARS. Insulators for the Delta Star Metal-Clad Switchgear were subjected to a breakdown test of 35,000 volts for a duration of one minute. Of the 366 Bakelite Insulators tested, only two failed—one at 33,000 volts and one at 29,000 volts. Insulators of another make and type of material were subjected to the same test and of the 133 tested nine failed. These tests provide a clear demonstration of the superiority of Bakelite Insulations for this class of service.



CIRCUIT BREAKERS. ITELITE circuit breakers are completely housed in Bakelite Molded cases. The rear section, is formed in one piece with all necessary lugs, bosses, channels, recesses, through holes, and partitions molded in. Threaded metal inserts for mounting electrical parts and for terminals are firmly embedded in the molding operation. The dielectric strength of Bakelite Molded simplified the insulation problem and provided a "dead front" for the devices.



HEAVY DUTY RECEPTACLES. Appleton armor-clad, heavy duty, "explosion-proof, dead-end" Unilet receptacles and plugs required molded insulation parts of the most substantial and durable insulation material available. After being subjected to rigorous tests Bakelite Molded was selected. In addition to high insulation value and physical strength, Bakelite Molded provided other advantages. Close dimensions were assured and consequently complete interchangeability made certain.



TIME CONTROLS. "Mount it anywhere", the makers tell purchasers of the new Paragon Time Controls. One reason this is possible is the use of Bakelite Molded for insulation parts. Terminal blocks, socket mountings, switches and base insulators have the high resistance to moisture and extremes of heat and cold for which Bakelite Molded is known. Besides providing thoroughly dependable insulation Bakelite Molded also aided in attaining compact design and economical production.

THESE ARE but four examples of the many new designs of electrical apparatus and devices in which valuable improvements have been effected through the use of Bakelite Materials. Electrical engineers and manufacturers will find much helpful information about a variety of Bakelite Materials in Booklets 33M, "Bakelite Molded", 33L, "Bakelite Laminated" and 33V, "Bakelite Varnish". Your request will bring copies promptly.

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THE MATERIAL OF A THOUSAND USES